Ontario

Report of the Royal Commission on the Health and Safety of Workers in Mines

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James M. Ham
Commissioner

Frederick R. Hume, QC
Counsel

Dr Cameron C. Gray
Medical Consultant

Arthur L. Gladstone
Executive Secretary

Jean Beaudry
Labour Adviser

Edmund A. Perry, P.Eng.
Engineering Adviser

R. Peter Riggin
Industrial Adviser

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Executive Secretary

The Royal Commission
on the
Health and Safety of
Workers in Mines

416/965-9512

Suite 1320
2 Carlton Street
Toronto Ontario
M5B 1J3

To Her Honour,
The Lieutenant Governor of
The Province of Ontario

May It Please Your Honour:

On the 10th day of September, 1974, I was appointed Commissioner to investigate matters related to the health and safety of workers in mines. Having performed the duties as set out in the Order-In-Council, I submit herewith my report.

30 June 1976.

James M. Ham

James M. Ham,
Commissioner.

OC-2340/74

Copy of an Order-in-Council approved by Her Honour the Lieutenant Governor, dated the 10th day of September 1974

The Committee of Council have had under consideration the report of the Honourable the Attorney General, dated September 6, 1974, wherein he states that,

WHEREAS this Government has concern in relation to the health of workers in the mines of this Province, and

WHEREAS some reasonable doubt has been cast on the effectiveness of present safety programs, and

WHEREAS it is thought fit to refer these matters to an Inquiry instituted pursuant to the provisions of The Public Inquiries Act, 1971, S.O. 1971, Chapter 49.

The Honourable the Attorney General therefore recommends that pursuant to the provisions of The Public Inquiries Act, 1971, S.O. 1971, Chapter 49, a Commission be issued to appoint Dr James Milton Ham, Sc., Dr.: –

1. To investigate all matters related to health and safety involved in the working conditions and working environment in mines in Ontario;

2. To identify the relevant data related to silicosis, lung cancer and other occupational health hazards of miners in Ontario;

3. To review the present basis for Workmen's Compensation Board awards as they relate to environmental health matters affecting miners; and

4. To make such recommendations in relation to 1, 2 and 3 above as are by him deemed to be appropriate.

The Honourable the Attorney General further recommends that all Government Ministries, Boards, Agencies and Commissions shall assist Dr James Milton Ham to the fullest extent in order that he may carry out his duties and functions and that he shall have authority to engage counsel, expert technical advisers, investigators and other staff as he deems proper at rates of remuneration and reimbursement to be approved by the Management Board of Cabinet.

And the Honourable the Attorney General further recommends that Part III of the said Act be declared to apply to the aforementioned Inquiry.

The Committee of Council concur in the recommendations of the Honourable the Attorney General and advise that the same be acted on.

Certified,

J.J. Young
Clerk, Executive Council

Contents

Preface

The report has the following structure. The first chapter identifies the agencies of government, industry, and labour concerned with the health and safety of workers in mines, illustrates the kinds of injuries and disease that produce loss of well-being, and points towards the issues of policy that underlie the report. The subsequent chapters on 'Silicosis and dust,' 'Lung cancer and ionizing radiation,' 'Accidents and injuries,' and 'Other environmental hazards at the workplace' represent case investigations of particular problems. The pattern of my recommendations arises out of the concrete context of these analyses. The concluding chapter explains the implications of these recommendations for provincial policy on occupational health and safety and recommends a change in legal and administrative arrangements for the mining industry.

The Commission established quarters, acquired staff, and began active work in mid-October 1974. Following an initial period of exploratory investigations in mines and plants and with agencies of government, industry and labour, the first period of hearings was initiated in Elliot Lake on 14 January 1975. These hearings were held in the northern communities of Elliot Lake, Red Lake, Thunder Bay, Sault Ste Marie, Sudbury, Timmins, and Kirkland Lake, and in Toronto and Ottawa.

Following the first period of hearings, which was substantially completed in mid-February 1975, the Commission extended its investigations and initiated research on industrial disease and injuries. The second and final period of hearings was held in Toronto from 26 May to 6 June 1975. Thomas Conlin acted as court reporter. A list of all briefs presented to the Commission together with cross references to the transcript of the hearings is given in appendix B. This material has been filed for public reference in the Provincial Archives of Ontario.

The Commission is indebted to a host of persons in the mining companies, the unions, and ministries of government and to individuals who contributed information and understanding in the course of the hearings and associated investigations. Not least important has been the rewarding personal experience of meeting miners at work. In the Province the Mines Accident Prevention Association, the Mines Engineering Branch in the Ministry of Natural Resources, the Ministry of Health, the United Steelworkers of America, and the Workmen's Compensation Board assisted the Commission continuously. The work of the Commission benefited from consultations with the staff of the Atomic Energy Control Board and of Atomic Energy of Canada Ltd.

In November 1975 the Commission visited mines, labour unions, and government agencies responsible for occupational health and safety in Sweden and the United Kingdom, and consulted the International Labour Office and the World Health Organization. Dr Cameron C. Gray, medical consultant, made visits to specialists in occupational medicine in Germany, the United Kingdom, and the USA.

During the fall of 1975 and the spring of 1976 the research projects were completed. Studies conducted for the Commission are listed in appendix E. Appendix C interprets the evidence obtained for risk of lung cancer in relation to radiation exposure among uranium miners on the Uranium Nominal Roll. The related mortality experience of these miners is discussed in chapter 3. This project was supervised for the Commission by Professor David Hewitt, Department of Preventive Medicine and Biostatistics, University of Toronto, with the personal co-operation and assistance of John Silins, chief, Vital Statistics Section, Health Branch, Statistics Canada; the Registrars General of all the provinces; W.C. Wheeler, supervisor, Statistical Analysis Section, Workmen's Compensation Board; Dr Jan Muller, chief, Environmental Health service, Ministry of Health; Dr Charles Stewart, chest disease consultant, Workmen's Compensation Board; and Peter McCrodan, Director, Mines Engineering Branch, Ministry of Natural Resources. I am deeply grateful for the spirit of co-operation that made this study possible in the short time available to the Commission. It is imperative that this study be extended to gain the full benefits of Ontario data.

Finally, I owe a personal debt of gratitude to each of the persons associated directly with me in the work of the Commission. Each has contributed unstintingly to the objectives and to my understanding. Frederick R. Hume QC, the counsel, is a principal in the firm of Hume, Martin, and Timmins. Dr Cameron C. Gray, the medical consultant, is executive vice-

president of the Ontario Lung Disease Association and associate professor in the Department of Medicine, University of Toronto. Jean Beaudry, the labour adviser, is a member of the staff of the United Steelworkers of America. Edmund A. Perry, the engineering adviser, is a representative for the mining branch on the Council of the Association of Professional Engineers of Ontario. R. Peter Riggin, the industrial adviser, is vice-president corporate relations, Noranda Mines Ltd. The executive secretary, Arthur L. Gladstone, managed the operations of the Commission in an exemplary manner and provided stimulating criticism of the formulations of the issues. Michael Evans and Daniel Pearlman ably served for a time on the staff of the Commission. Marilyn Lefolii and Marilyn Flynn meticulously prepared the report from handwritten manuscript. I am grateful to Larry MacDonald of the University of Toronto Press for carefully editing the report.

Frederic LePlay, a distinguished French sociologist and inspector general of the mines of France in the late nineteenth century, said that the most important thing to come out of mines is the miner. I share his conviction today.

REPORT OF THE ROYAL COMMISSION ON THE HEALTH AND SAFETY OF WORKERS IN MINES

1

The issues in health and safety in the mining industry

THE NETWORK OF RESPONSIBILITY

Intense public concern about the effect of human activity on the quality of the outer environment of air, land, and water has developed within the past decade. There is now a growing concern about the health and safety of persons at work in the inner environment of their working places in industry. The hearings and investigations of the Commission have confirmed that this concern, when focused on the health and safety of workers in our mines, is well justified.

In Canada the ownership of mineral resources and the control of their extraction, except for uranium, is vested under the British North America Act in the provinces. In Ontario the statutory basis for health and safety provisions in the mining industry can be found in the Mining Act, and in particular in Part IX.[1] Part IX of the Mining Act places upon the management of a mine the responsibility to ensure that its provisions are met.[2] Equivalent legal instruments in many countries do likewise. In the hearings before the Commission this managerial prerogative has been challenged.

Since ores of uranium are mined in Ontario and since the respiratory diseases of lung cancer and silicosis among workers in the uranium mines have been of special concern in hearings before the Commission, the exceptional federal jurisdiction relating to the extraction of uranium is important. With the advent of nuclear weapons and of nuclear power, the Government of Canada exercised an imputed right, under a general provision of the British North America Act regarding 'peace, order and good government,' to assume control of the extraction of uranium ores. This it did by passing the Atomic Energy Control Act, which is administered by the Atomic Energy Control Board.[3] The Board has exercised its authority

under the Act to issue licences for the operation of uranium mines in Ontario, one provision of which invokes provincial regulations concerning the health and safety of workers at these mines.[4] The regulations under the Atomic Energy Control Act also include allowable exposures to radiation for workers designated as radiation workers.

The role of the Board in matters of health and safety in uranium mines in Ontario will be considered in this report. The special circumstances for uranium notwithstanding, the administration of the Mining Act by the Ministry of Natural Resources (and formerly the Department of Mines) provides the basic structure of regulation and enforcement. Enforcement of Part IX of the Mining Act is carried out under Section 610 by an inspectorate consisting primarily of professional engineers under the technical direction of the director of the Mines Engineering Branch in the Ministry of Natural Resources. The role, composition, and performance of this inspectorate were strongly criticized in many hearings before the Commission. The functioning of this inspectorate will be reviewed.

When the Commission began its work in October 1974, the role of the Ministry of Health in relation to mines and mineral plants was to provide assistance to the Ministry of Natural Resources on the basis of requests received. Through this administrative practice, the Occupational Health Protection Branch of the Ministry of Health and its forerunners have played an important but undesirably restricted role in health problems of mine workers. The role of an Occupational Health Authority will be considered.

When a person is injured in an accident at work or contracts an industrial disease attributable to conditions at the workplace, he receives partial wage compensation and related medical and rehabilitative services through the Workmen's Compensation Board, which administers the Workmen's Compensation Act.[5] The Board, which is responsible to the minister of labour, receives claims for accidents and diseases associated with the conditions and place of work and establishes administrative practice for the compensation of diseases and accidents. The adequacy of the basis for compensation used by the Board in relation to certain occupational health hazards in mines was challenged in the public hearings before the Commission, and in accordance with the terms of reference some recommendations in this regard will be made.

Under Section 119 of the Workmen's Compensation Act, 'the employers in any of the classes for the time being included in Schedule 1 may, with the approval and under the control of the Board, form themselves into an association for the purposes of education in accident prevention.' The

employers under Class 5 of Schedule 1,[6] consisting mainly of mines and their associated plants, formed in 1930 what is now called the Mines Accident Prevention Association of Ontario. Membership in the MAPAO of all employers under Class 5 is obligatory. This association is one of a number of organizations formed in a similar fashion in other sectors of industry. The operations of the MAPAO are funded by the Workmen's Compensation Board from the levies against employers authorized under the Act.

Closely related to the MAPAO, and indeed sharing the services of the same executive director, is the Ontario Mining Association, a voluntary industrial association of corporations operating mines, reduction plants, or like businesses. The OMA is the older organization, and the MAPAO was formed on its initiative.

These are the major institutions for the involvement of government, and for the collective involvement of industry, in issues related to the health and safety of workers in mines. Each of them has been subjected to sharp criticism by labour unions, and particularly by the United Steelworkers of America. To investigate this criticism the Commission has found it helpful to use the concept of a responsibility-system for health and safety encompassing the roles of all parties involved. The scope of this responsibility-system is related to five basic factors which, in the Commission's opinion, together determine the levels of occupational risks in our mines. Whether in the home or the factory, on the highway, or in the mine, there is no attainable state of absolute health and safety. There are levels of risk accepted or tolerated to a degree by the parties concerned. Mines can only exist where economically viable operations can be conducted. Within operating mines, the acceptable levels of occupational risk are determined by: 1/ the quality and kind of industrial management and supervision; 2/ the degree of participation and commitment from employees, individually and collectively in labour unions or otherwise; 3/ the state of social expectation and concern in mining communities and in the public at large; 4/ the measure of political attention as expressed in legislation, in the related governmental administrative practices for monitoring compliance, and in the provision of compensation; and 5/ the combined effectiveness of the above parties in operating as a system.

Underlying the first four factors is a complex structure of relationships between worker, supervisor, management, union, industry, government, and the public. The following sections of this report, in attempting to assess the many allegations that have been levelled at the current responsibility-system, will look in some detail at the sources of specific problems of health

and safety now existing in our mines. The object of these studies is to clarify the role and future responsibility of the participants.

The responsibility-system seems to have been lacking in two significant ways. First, divided jurisdictions have made it unclear where the initiative necessary to deal with problems is to be taken. Second, the worker as an individual and workers collectively in labour unions or otherwise have been denied effective participation in tackling these problems; thus the essential principles of openness and natural justice have not received adequate expression. Participation may be understood in terms of the following three major elements: 1/ knowledge – having ready access to information about actual and expected conditions at the workplace, and about the state of the health of the workers; 2/ contributive responsibility – to provide individual and collective insight on problems on the basis of knowledge and work experience; and 3/ direct responsibility – to make operative decisions that influence conditions at work.

The problems of the health and safety of workers in mines discussed in this report are probably not peculiar to the mining industry.

THE INDUSTRY, THE WORKPLACE, AND THE HAZARDS OF WORK

Mining is concerned with discovering and delineating useful bodies of materials in the earth's crust, and with removing and processing such materials into economically viable primary products. In Ontario the materials mined are grouped as metallic, non-metallic, structural, and fuels.[7] Metallics include uranium oxide and such metals as nickel, copper, iron and gold; non-metallics include gypsum, salt, sulphur, and asbestos; structural materials include sand, gravel, clay, and stone; fuels include coal, natural gas, and petroleum. Briefs to the Commission associated with specific mining operations related entirely to the mining and processing of metallic and non-metallic materials. The substance of this report is therefore addressed to the problems of health and safety in these sectors of the industry, which currently employ some 38,000 persons.[8]

The geographical distribution of current metallic and non-metallic mining operations is shown in Figure 1. This sector of the industry accounts for about 85 per cent of the gross value of all mineral production, which in 1974 toalled $2.5 billion and represented 4.5 per cent of the Gross Provincial Product.

Currently, the workers at metallic and non-metallic mines are employed by forty companies operating sixty-three underground or open-pit mines

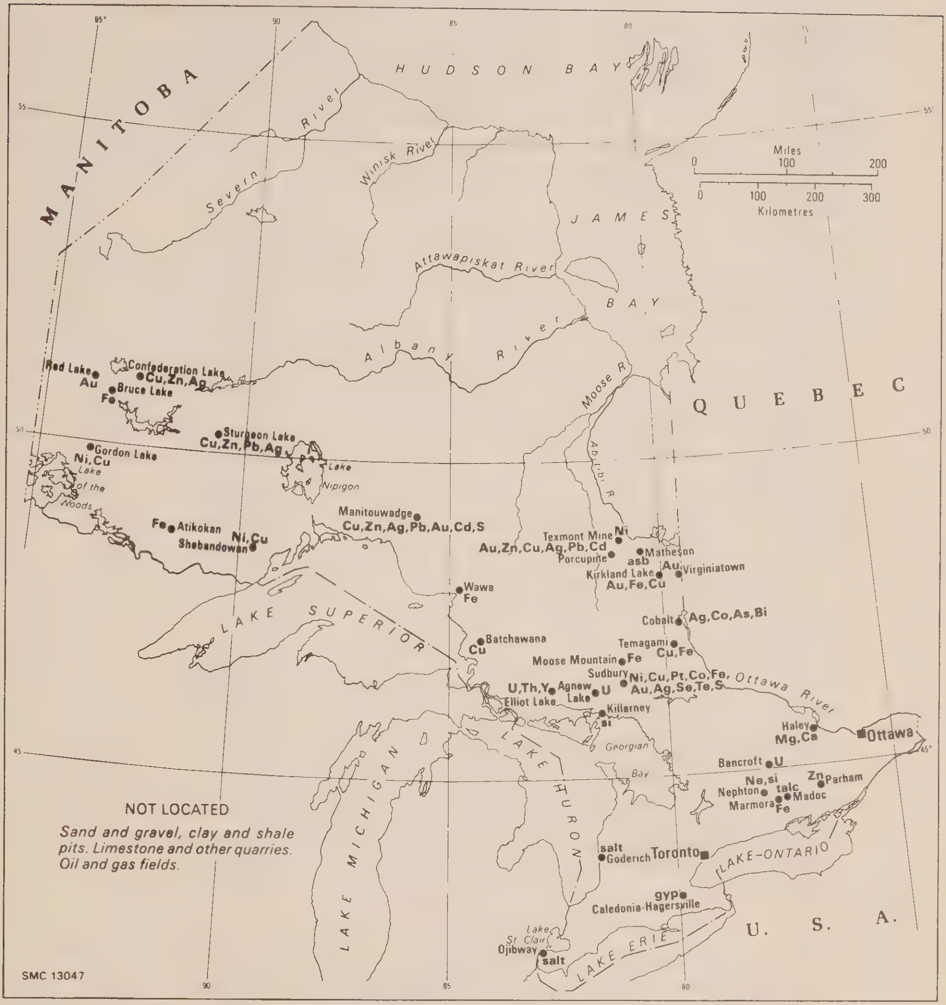


FIGURE 1 Geographical distribution of current metallic and non-metallic mining operations in Ontario.

and related ore processing and refining plants as grouped in Table 1. The contractors are private operators hired by the mines to conduct diamond drilling for the delineation of ore bodies and to sink shafts and develop headings as part of mine development.

Well over one-half of the workers are in the nickel-copper mines concen-

TABLE 1

Distribution of employees by material mined and by contractor type as of December 1974

Type of material	Companies (N)	Mines (N)	Employees (N)	Employees (%)
Metallics				
Nickel-Copper	4	25	23,500	61.8
Iron	7	8	3,700	9.7
Gold	8	9	3,400	8.9
Copper-Zinc	8	8	3,200	8.4
Uranium Oxide	2	2	1,630	4.4
Magnesium	1	1	300	0.8
Silver	2	2	150	0.4
Total	32	55	35,880	94.4
Non-metallics				
Salt	2	2	450	1.2
Nepheline Syenite	2	2	200	0.5
Asbestos	2	2	170	0.4
Quartz	1	1	80	0.2
Talc	1	1	40	0.1
Total	8	8	940	2.5
Contractors				
Sinking and development			780	2.0
Diamond drilling			400	1.1
Total			1,180	3.1
Over-all total	40	63	38,000	100

NOTE: Employees in Class 5 under the Regulations of the Workmen's Compensation Act, excluding prospectors. Numbers of employees are rounded.
SOURCE: Mines Accident Prevention Association of Ontario, *Annual Report*, Toronto, 1975, 19–20; and company reports to the Commission.

trated in the Sudbury basin. Workers in the uranium mines now represent just over 4 per cent of all employees, and all of the non-metallic mines together employ just over 2 per cent of workers. The gold mines, which historically were the major source of the industrial disease silicosis, employed some 75 per cent of workers in 1940 but currently employ only 9 per cent.

Table 1 indicates a great variety in the number of employees per company. This wide range of scale extends to the number of employees active at the different types of workplace within corporate mining operations. The employees at a given operation may be divided into five categories of

personnel. These are management/supervisory, accounting for 10 per cent of the total, clerical (5 per cent), engineering/technical (5 per cent), skilled trades (15–45 per cent) and semi-skilled and unskilled (65–35 per cent). The lower percentage for skilled trades and the higher percentage for semi-skilled and unskilled is attained at operations concentrating on underground mining.

Workplaces and their hazards

The employees of a producing mining property which is developing, for example, a metallic mineral body are distributed among the following characteristic operations, all of which may not be conducted at a single geographical location: 1/ drilling a pattern of holes in the ore; 2/ breaking the ore by loading the drilled holes with a blasting agent and firing the round; 3/ collecting the broken ore (muck) and transporting it to a primary crusher; 4/ transporting the crushed ore to, and passing it through, a sequence of secondary crushing and grinding operations to produce a mixture of fine particles; 5/ separating the particles of valuable mineral from the particles of waste material in the ore by gravitation, flotation, or related methods to produce a mineral concentrate; 6/ extracting the valuable fraction of the mineral by pyrometallurgical or hydrometallurgical treatment of the concentrate, followed by refining to produce primary metal; and 7/ managing and servicing the above operations.

These operations may be grouped to define four types of workplaces, which are characterized by distinctive hazards to health and safety and for which accident statistics have been segregated. Operations 1 to 3 inclusive are characteristic of mining both in underground mines and open pits; 4 to 6 inclusive occur in reduction plants usually located on the surface; and 7 represents, in addition to the administrative centre of the mining operation, technical shops, private railways, and related road transportation systems.

Table 2 gives the approximate current distribution of the workforce in the metallic and non-metallic sector of mining by the above types of workplace. Within a particular mining operation the percentage distribution may vary significantly from the averages shown for the whole sector. The high percentage in servicing is indicative of the high measure of mechanization in the industry in Ontario.

The extraction of ore involves the continuous development and extension of a network of passages, known as shafts, crosscuts, and drifts, and of rooms in the ore body and associated waste rock, known as stopes. The pattern of this network in any given mine depends on the orientation, shape, and size of the ore body and on the method of mining adopted, such

TABLE 2

Distribution of work force by class of workplace in 1974

Workplace	Workers (N)	Workers (%)
Mining	14,000	37
Underground	12,000	32
Open pit	2,000	5
Reduction plants	7,000	18
Total Mining and reduction plants	21,000	55
Servicing	15,800	42
Diamond drilling	400	1
Sinking and development	800	2
Total	38,000	100

NOTE: Servicing places are those designated Shops and Surface by the Mines Accident Prevention Association. As noted in relation to Table 3, Diamond drilling and Sinking and development workers are associated with private contractors who contract with mines to develop shafts and headings for underground mines and to provide diamond drilling to delineate ore bodies.

SOURCE: Figures derived from the Mines Accident Prevention Association of Ontario, *Annual Report*, Toronto, 1975, 14

as room-and-pillar, cut-and-fill, and sublevel-caving. The rock surfaces of the network have properties peculiar to the geology of the ore and the host rock. These properties change from place to place within individual mines and between different mines, and so, therefore, do the day-to-day locations and surrounding conditions of workplaces. These circumstances make work in a mine singularly different from that at fixed and stable places such as factories.

Because underground networks may extend for miles and ore extraction is highly mechanized, men are scattered widely, and the supervision of work is more difficult than in plants. Furthermore, in most but not all underground mines and open pits in Ontario, workers engaged directly in extracting and transporting ore are paid on an incentive-contract basis, providing a base wage supplemented by a bonus keyed to the production achieved on a shift-by-shift basis. Only a few workers in plants are paid this way. It has been debated whether or not the bonus system increases the likelihood of accidents.

The potential hazards in the enclosed spaces underground are many. There is the threat of rock movement and of the fall of loose rock. The

machines used in mining generate intense noise. The inherently destructive nature of blasting precludes the use of permanently installed lighting at the working face. The regular processes of drilling, blasting, mucking, and crushing generate fine respirable mineral dusts which are potential causative agents in pneumoconiosis (literally 'lung-dust-disease'). Compressed air drills release oil mist; diesel engines emit soot and a complex variety of chemical particulates and gases. Development blasting and secondary blasting release significant amounts of dust and potentially noxious gases. The radioactive gases radon and thoron emanate from rock faces and arise from the elements uranium and thorium which are present in many rock formations, especially in uranium mines. Also, in the deepest mines, working temperatures and humidity may be high.

Whether or not these risks lead to accidents and industrial disease depends on a complex of factors, some of them determined beyond the workplace but many others depending intimately on how work is supervised and performed. From the outside, statutory regulations establish standards for dust and other aerosols, for radiation, noise, exposure to chemicals, and for the safe development and operation of mines, mining systems, equipment, and services. Within a mine, the control of rock movement depends on mine design and rock-support methods such as roof bolting. The reduction of injuries from 'loose'[9] depends on work practices in scaling the developing rock surfaces. The loading, hauling, and dumping of muck is a perennial source of accidents, prevention of which depends on skill and care in the use and maintenance of heavy machinery. The level of respiratory hazard from the air breathed at the workplace depends on the effectiveness of the ventilating system in diluting and sweeping out airborne gases and particulates and upon such work practices as wet drilling, blasting at the end of shifts, and wetting down broken rock. Safety boots, hard hats, safety glasses, ear plugs, ear muffs, respirators, gloves, and special clothing are among the personal items of equipment used in mines to provide physical protection to the worker by 'enclosing' him. But not all workers are disposed to make meticulous use of such devices when they are available.

In reduction plants the mineral materials being processed with various chemical reagents and heat are completely or partially enclosed within process equipment having, except for the use of cranes and the like, a fixed arrangement. Health and safety hazards distinctive to reduction plants are associated with the leaking or splashing of potentially dangerous materials into the work area. These materials include molten metals, chemical reagents, and process gases such as sulphur dioxide and nickel carbonyl.

The reality of the hazards in the mines and plants is in the end determined by the record of events. To complete a background for assessing how the responsibility-system has dealt with particular hazards, the spectrum of accidents and cases of industrial disease compensated by the Workmen's Compensation Board in 1974 will now be reviewed.

THE SPECTRUM OF ACCIDENTAL INJURIES AND CASES OF RECOGNIZED INDUSTRIAL DISEASE IN 1974

The purpose of surveying industrial diseases at one moment in time is threefold. First, it places on public record a list of events in 1974 which resulted in a loss of well-being of workers attributable to the workplace in mines and plants as judged on the basis of awards made by the Workmen's Compensation Board. Second, it illustrates the distribution of such events

TABLE 3

Fatal accidents during the year 1974 in Class 5 of the Workmen's Compensation Act

Workplace	Fatalities
Mining	
Underground	15
Open pit	1
Reduction plants	–
Servicing (shops and surfaces)	–
Contract diamond drilling	–
Contract sinking and development	1
Prospecting	3
Total	20
Cause	**Fatalities**
Haulage of material	6
Fall of ground	5
Fall of person	3
Explosives	2
Runs of Muck	1
Drowning	1
Fatigue	1
Suffocation	1
Total	20

SOURCE: Mines Accident Prevention Association of Ontario, *Annual Report*, Toronto, 1975, 16

TABLE 4

Non-fatal compensable accidents during the year 1974 in Class 5 of the Workmen's Compensation Act

Workplace	Injuries (N)	Injuries per million man-hours worked (N)
Mining		
Underground	1,950	90.8
Open pit	57	13.9
Reduction plants	1,147	89.2
Servicing (shops and surface)	403	13.7
Contract diamond drilling	94	85.0
Contract sinking and development	48	27.9
Prospectors, etc.	119	59.5
Total	3,818	53.8

Principal cause	Injuries (N)	Proportion of total (%)
Slips and falls	939	24.6
Over-exertion (primarily back injuries)	681	17.8
Striking, struck by, objects	651	17.1
Caught between objects	418	11.0
Rock falls	291	7.5
Falling objects	220	5.7
Inhalation, contact absorption, ingestion[a]	163	4.3
Extremes of temperature[b]	114	3.0
Flying objects	90	2.4
Nails and splinters	75	2.0
Runs of muck	33	0.9
Explosives	16	0.4
Other	127	3.3
Total	3,818	100.0

NOTE: Compensable accidents entail an absence from work for one or more days following the date of the accident.

a Including 107 instances of a foreign body in the eye, 15 instances of a caustic substance in the eye, 11 instances of inhalation of toxic gases and 11 cases of contact dermatitis.

b Including 66 incidents involving hot materials such as steam, liquids including molten metals, and 17 incidents with cutting and welding.

SOURCE: Mines Accident Prevention Association of Ontario, *Annual Report*, Toronto, 1975, 14–15; and Commission research on compensable injuries

TABLE 5

Recognized cases of industrial disease first compensated during 1974 in Class 5 of the Workmen's Compensation Act

	Metal group charged	Cases: Unspecified	Cases: Underground or open pit	Cases: Reduction plants	Causative agent
Silicosis	Uranium		21		
	Gold		11		
	Other than uranium and gold		10		Respirable dust containing free silica
	Total		42		
Cancer	Uranium		8	–	*Uranium*: The major contributing causative agent peculiar to the workplace is considered to be exposure to radiation from the disintegration products of radon gas called radon daughters. The eight cases of lung cancer are associated with seventeen uranium mines opened at Bancroft and Elliot Lake in the period 1955–74. Only two of these mines are now operating. *Nickel*: These cases, seven of which were sinus cancer and thirteen lung cancer, are associated with calcining, sintering, and cupola furnace operations in reduction plants in the nickel industry. The operation of the processes involved was terminated at one location in 1958 and at the other in 1963. *All other*: The one case of lung cancer associated with an open pit was charged to an asbestos mine, and the two cases of lung cancer in reduction plants are currently associated with arsenic in a silver and cobalt oxide refinery that ceased production in 1961.
	Nickel		–	20	
	Gold		–	–	
	All other		1	2	
	Subtotals		9	22	
	Total		31		
Loss of hearing		213			Industrial noise

NOTE: Compensated cases of hearing loss included first disability awards only.
SOURCES: For silicosis: Mines Accident Prevention Association of Ontario, *Annual Report*, Toronto, 1975, 18, as updated to show the final figures for the year. For cancer: data provided by the Workmen's Compensation Board. For loss of hearing: Workmen's Compensation Board, Medical Statistics Unit.

among workplaces by various causes where these are known. Third, it identifies the distinctive issues of policy that must be dealt with by the responsibility-system in recognizing and responding to accidents and industrial disease.

Practices in reporting accidents and industrial disease differ notably in different jurisdictions. It is important therefore to define clearly the conditions for the inclusion of an event in this review. Each event is one for which the Workmen's Compensation Board authorized payments in maintenance of partial wages or for pensions. Accidents involve traumatic events such as fractures, sprains, burns, and inhalations that occur at specific times at the place of work. Compensable accidents as listed in

Tables 3 and 4 involve absence from work for one or more days following the day of the accident.

Industrial diseases include respiratory diseases such as certain types of lung cancer, silicosis, asbestosis, other forms of pneumoconiosis, and loss of hearing. Although each of the cases reported in Table 5 was recognized for compensation for the first time in 1974, the elapsed time to recognition from initial exposure to the known or suspected causative agent(s) extended over a period of years. For example, the average elapsed time to recognition from first exposure to respirable dust containing free silica for the twenty-one new cases of silicosis among uranium miners was twenty-four years. Since workers move from job to job, the exposure to dust of a given person may not all have occurred in Ontario, in one type of mine, in one particular mine, or at one class of workplace. Industrial disease of the types cited is experienced throughout the remaining life of the person and is attributed to past working conditions. Personal habits such as smoking modify and often greatly increase the likelihood of the onset of industrial disease.

The accident experience for Class 5 under the Workmen's Compensation Act for 1974 is summarized for fatal injuries (Table 3) and for non-fatal injuries (Table 4). The cases of industrial disease recognized in 1974 are listed in Table 5 with brief notes on causative circumstances. Not included in Table 5 are medical-aid-only events not entailing loss of a day at work but reported to the Board for payment of medical expenses, and that part of light-duty work assignments made by the employer which do not involve compensation by the Board. These classes of events will be considered in chapter 4.

CONCLUSION

The following chapters outline how management, labour, and government have dealt with, and how the Commission feels they should deal with, the ongoing pattern of work-related injury and disease as reviewed in the tables. Accidents and industrial diseases pose for the responsibility-system distinctive sets of questions of policy concerning principles and practices for identification, prevention, and compensation. These sets of questions will provide the framework for problem analysis.

Let us briefly consider accidents. With the exception of symptomatic events such as back pain, accidents can be clearly identified as to time and place. Recognition for purposes of compensation is readily effected once

identification with the place of work is made. The key problems lie in the complex human origins of accidents and in the policies adopted to prevent them.

While careful design and effective maintenance of the work environment is important, relatively few accidents are the result of technical or physical defects that are independent of the personal act of work. The great majority of accidents arise out of the act of work itself. Hence the responsibility-system must have well-defined policies and practices with respect to the following subjects: the organization of work, the design of work practices, the performance of work, the supervision of work, the monitoring and control of the system of work, and the value system operative at the workplace.

The worker and his immediate supervisor, the shift boss, are centrally involved in and share an inescapable measure of direct responsibility for working safely. That this is peculiarly true in mining is evidenced by the fact that when a shift boss visits a work crew all work stops while the situation is discussed. The Commission, having accompanied shift bosses through the tortuous drifts of gold mines and through the amphitheatre-like stopes of nickel mines to talk with the men, has become convinced that participative responsibility in the act of work is, and will remain, a key to accident prevention.

Further, the hearings and investigations of the Commission have suggested that the basis of confidence for the exercise of this responsibility by the worker, the shift crew, and the shift boss is being eroded because the roles of the different parties in the responsibility-system as a whole are not clearly and mutually understood and accepted. Lack of information and of openness to the contributive participation of labour in the responsibility-system as a whole, changing attitudes in management, and a changing social basis for discipline at the workplace, all further erosion of trust. The worker, the shift boss, the union, and management must work together to restore a sense of mutual responsibility for working conditions.

Let us now briefly examine the central questions of policy that are posed for the responsibility-system by industrial disease. Whereas accidents arise principally out of the personal act of work, industrial disease is related primarily to the environment of the workplace, which although influenced by work practices is largely beyond the control of the worker. Dust, radiation, noise, and noxious gases are intrinsic to mining. And major problems exist with respect to the identification, prevention, and compensation of industrial disease. To deal effectively with these, the responsibility-system must have well-defined policies and practices on

the following operational questions: identifying disease attributable to the workplace, identifying causative agents and other hazardous substances in the environment of the workplaces, setting standards for hazardous substances to prevent disease, monitoring concentrations of hazardous substances at the workplace, ensuring biological surveillance of the state of health of the workers, identifying and diagnosing cases of disease, accepting cases of disease for compensation, and communicating information on these issues to the affected parties. The effectiveness of the responsibility-system in these matters depends critically on the quality and extent of statistical and personal records based on monitoring of environmental contaminants at the workplace and on biological surveillance of the worker.

In the hearings of the Commission there were allegations that the responsibility-system has failed to develop and to exploit for the protection of the worker an adequate set of properly linked records, and further that workers have not had reasonable access to the studies that have been carried out. In reporting on the problems of silicosis and dust and of lung cancer and radiation, this central problem of medical and engineering records, access to them and their use, will be addressed.

All policy recommendations in this Report result from detailed investigation of particular problems.

1 *Revised Statutes of Ontario (RSO), 1970*, The Mining Act, c. 274, as amended to August, 1972. Parts IX and XI of the Mining Act are, for easy reference, published in a manual entitled *Handbook of Requirements Governing the Operations of Mines (being Part IX and Sections 621, 624, 625 (1) (a) (b) (c) (2) & (3) and 626 of Part XI of the Mining Act)* (Toronto: Queen's Printer, 1971). Henceforth all references to sections in Part IX and XI of the Mining Act will be taken from the *Handbook*.
2 Mining Act, s. 169 (13).
3 *Revised Statutes of Canada (RSC), 1970*, Atomic Energy Control Act, 1946, c. A-19. Henceforth cited as *Atomic Energy Control Act*.
4 The collective bargaining units representing the workers in Ontario uranium mines have been certified under the Canadian Labour Code. All other union locals in mines in Ontario are certified under the Ontario Labour Code.
5 *Revised Statutes of Ontario (RSO), 1970*, The Workmen's Compensation Act, c. 505, as amended to July 1974. Henceforth cited as Workmen's Compensation Act.
6 Workmen's Compensation Act, Reg. 834, Schedule 1, Class 5.
7 Ontario Ministry of Natural Resources, *Ontario Mineral Review 1974*.
8 The employees in this group form the major part of those covered by Class 5 of Schedule 1 under the regulations of the Workmen's Compensation Act. The major subgroup of Class 5 excluded from the Commission's study are the prospectors, whose numbers fluctuate but currently total about two thousand.
9 Pieces of rock that may fall from the roof, which is known in the mining terminology as the 'back.'

2

Silicosis and dust

SILICOSIS AS A PNEUMOCONIOSIS

Silicosis, one of a group of diseases of the lungs termed pneumoconiosis, is caused by the inhalation over a period of years of dust containing free silica.[1] The latter is the chemical compound silicon dioxide, usually found in crystalline form and most commonly in Ontario as quartz. The percentage by mass of free silica in ore bodies in Ontario ranges from under 10 per cent up to about 70 per cent. Ontario ores of nickel in the Sudbury basin, and some ores of iron, contain up to 10 per cent free silica. Gold and copper ores contain 15 to 35 per cent, the uranium ores in the Bancroft area 5 to 15 per cent and the uranium ores in the Elliot Lake area 60 to 70 per cent.

The harmful free silica is that present in the dust inhaled by workers. While the amount of free silica in the respirable fraction of dust in mining operations may vary widely from place to place in a given mine, the likelihood of there being a significant percentage is directly related to the free silica content of the ore and host rock being broken. Silica dust is but one of several particulates commonly found suspended in mine air. These particulates generally include dust of the minerals mined and oil mist from drills, and may also include dust of rare earth elements, radioactive daughters of radon and thoron gas, and the emissions of diesel engines. In the sequence of jobs that mark the career of a typical mine worker, different aerosols formed from complex combinations of particulates are commonly inhaled. The influence on the lungs of a given complex aerosol and of a sequence of different aerosols is not fully understood.

A primary reaction of the lung to extended exposure to silica particles is to generate fibrous or scar tissue at dispersed locations initially in the upper

and posterior lung fields. The fibrous tissue gradually develops into a pattern of whorled nodules. The developing patterns of fibrous tissue can, in an otherwise normal lung, be recognized and classified into various radiographic categories. An initial abnormality may be called 'dust effects' and in Ontario be categorized as a number 4 on an integer radiological scale.[2] As the fibrogenic process in an otherwise normal lung intensifies into a system of dispersed nodules a few millimetres in diameter, the pattern is recognized as 'radiological silicosis' and assigned the number 5.

In the absence of complications, the most important of which is tuberculosis, the fibrous nodules of radiological silicosis do not themselves significantly reduce the large reserve of respiratory capacity in the human lung and therefore produce no disability apparent to the person. However, the fibrogenic reaction of the lung progresses both in and out of dust exposure and may lead to a gradual reduction in the elasticity of the lung. When pulmonary impairment is detected by clinical assessment the person is said to have the disease silicosis. If the disease progresses without complications, the affected person may first become aware of it through unexpected shortness of breath during periods of physical exertion.

Silicosis has been by far the most serious form of pneumoconiosis among workers in Ontario mines. But asbestos, nepheline syenite, and talc are other materials mined in Ontario the dusts of which are fibrogenic in varying degrees and produce pneumoconiosis in distinctive forms. To the end of 1974 no case of asbestosis had been recognized by the Workmen's Compensation Board as chargeable to the mining industry. There have been some twenty-five cases of pneumoconiosis attributed to nepheline syenite and talc operations in the mining industry.[3]

Dusts which do not produce a fibrogenic reaction in the lungs are called inert and include gypsum, limestone, and common salt, all of which are mined in Ontario. The property of inertness does not imply that such dusts in sufficient quantity are harmless.

SILICOSIS AND THE MINING INDUSTRY[4]

Silicosis and its major complication, silicotuberculosis, became compensable under the Workmen's Compensation Act in 1926.[5] When examining the development of the disease in the mining industry as a whole since that date it is important to note that silicosis and other related pneumoconioses are not confined to mining. In the years 1972 to 1974 inclusive, mining accounted for slightly more than half of the cases of pneumoconiosis

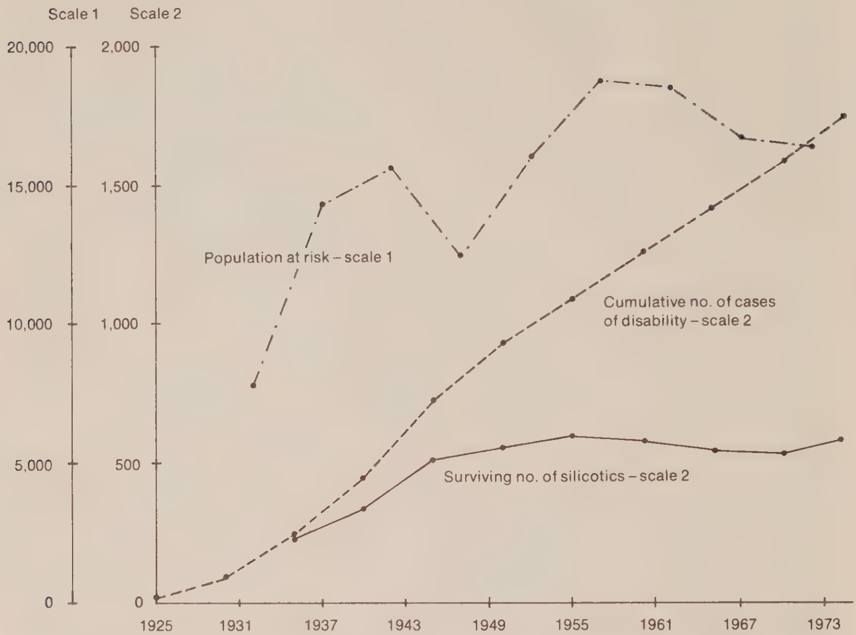


FIGURE 2 The development of silicosis in Ontario mines (Source: Workmen's Compensation Board, Silicosis Disability Index, November 1975)

recognized by the Workmen's Compensation Board. The remainder derived from such industrial activities as foundries and asbestos manufacturing.

The scope and evolution of the disease among workers in Ontario mines can be seen in Figure 2, showing the number of mine workers in dust-exposure workplaces since 1925, the cumulative number of new cases of silicosis, and the cumulative number of surviving silicotics.[6] The graph of cumulative new cases shows that some eighteen hundred cases have been recognized in Ontario in the fifty years from 1925 to 1975. Because of the long average latency period for the development of silicosis and the relative continuity of historical dust conditions, the approximately linear form of the graph of cumulative new cases cannot be expected to change rapidly in the immediate future. Hence a significant number of new cases may be expected to appear.

The graph of the population of surviving recognized silicotics shows that this number has been nearly constant. It has averaged 570 over the 25-year

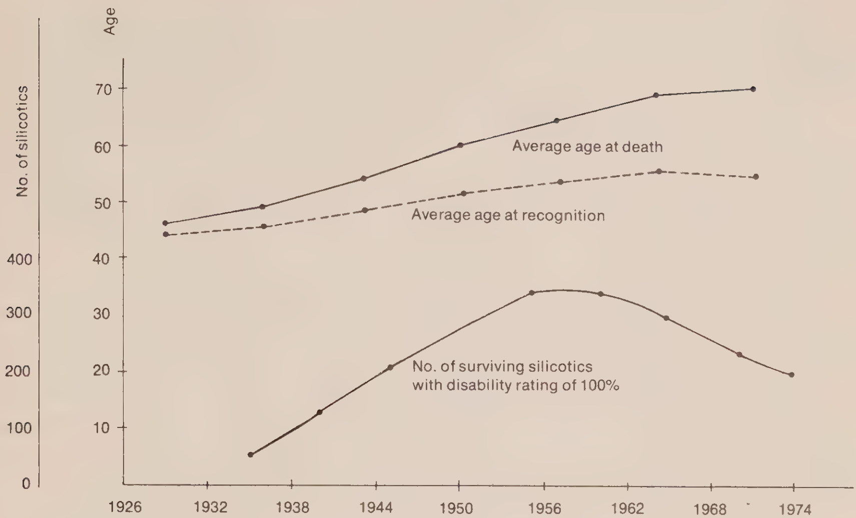


FIGURE 3 Age at recognition and death (Source: see Figure 2)

period from 1950 through 1974. This number has been nearly constant because the number of new cases of silicosis recognized per annum has been about equal to the number of silicotics dying per year. Over the corresponding period the average number of mine workers exposed to dust has been 17,500. Hence, the population of surviving silicotics has for some years been at the level of 3.3 per cent of the current population of dust-exposed workers. This figure provides a gross prevalence factor for the disease.

The experience of silicotics after recognition varies considerably from person to person depending upon age, severity of the disease, and other coexisting medical conditions. An indication of the impact of the disease on life and lifespan is given by the average age of silicotics at death in a given year and the average age at recognition of those silicotics who died in a given year. These characteristics are shown in Figure 3, along with the number of surviving silicotics who have been assigned a disability rating of 100 per cent for purposes of compensation.

The average age at first recognized disability of those silicotics who have died increased from forty-three years of age in 1926 to fifty-six years in 1974. For a male person having attained the age of fifty-six years, vital statistics of Canada (1960–2) indicate an additional life expectancy of 19.6 years.[7] The average number of survival years for silicotics who died in 1974

was sixteen years. Thus, the average lifespan of silicotics in Ontario is approaching the average life expectancy of Canadian males who have attained the average age at which silicotics who have died were recognized.

The number of surviving silicotics who have been assigned a disability rating of 100 per cent for purposes of compensation has been decreasing since 1960. Because the total population of surviving silicotics has been nearly constant since 1950, the proportion with a high disability rating has been decreasing, so that in a statistical sense the severity of the disease is decreasing.

Disease conditions other than silicosis are often present in silicotics assigned a high disability rating for purposes of compensation. Tuberculosis is the major disease to interact synergistically with silicosis. Paterson reviewed the status of tuberculosis among miners and the general population in a report issued in 1973.[8] His statistics, based on the records of the Ontario Mining Association and the Ministry of Health, showed that tuberculosis was present in seven out of eight deaths of silicotics recorded as occurring in 1926. Further, its incidence among persons x-rayed in the period 1967–72 was found to be four times as high among dust-exposed mine workers as among the general population. Data of the McIntyre Research Foundation show that in the period 1970–4 tuberculosis was present in 8 out of 145 deaths, or 5.5 per cent.[9] The Commission has examined the records of the Ministry of Health for tuberculosis among living miners for 1973 and 1974 and has found no evidence of a significant change in the incidence of tuberculosis during the annual radiographic surveillance from that reported in Table 7 of Dr Paterson's report. Tuberculosis continues to be present among living dust-exposed miners and at the death of silicotics at a much higher rate than in the general population. *The recommendations for continued vigilance in this regard given by Dr J.F. Paterson in 1973 are therefore fully endorsed.*

The encouraging trends noted above are in the severity of the disease following its recognition. The circumstances leading up to its first recognition are suggested in Figure 4, showing the average age of silicotics recognized in each year, the average elapsed time to silicosis from first dust exposure in Ontario, and the average percentage initial disability for those cases in which a percentage was assigned for purposes of compensation. The delay or latency in the development of silicosis is illustrated by the steady increase in average elapsed time from first dust exposure in Ontario to first disability, from fifteen years in 1926 to some thirty-five years about 1960, with a downward trend since then.[10] The corresponding increase in years of dust exposure in Ontario was about thirteen to twenty years,[11] the

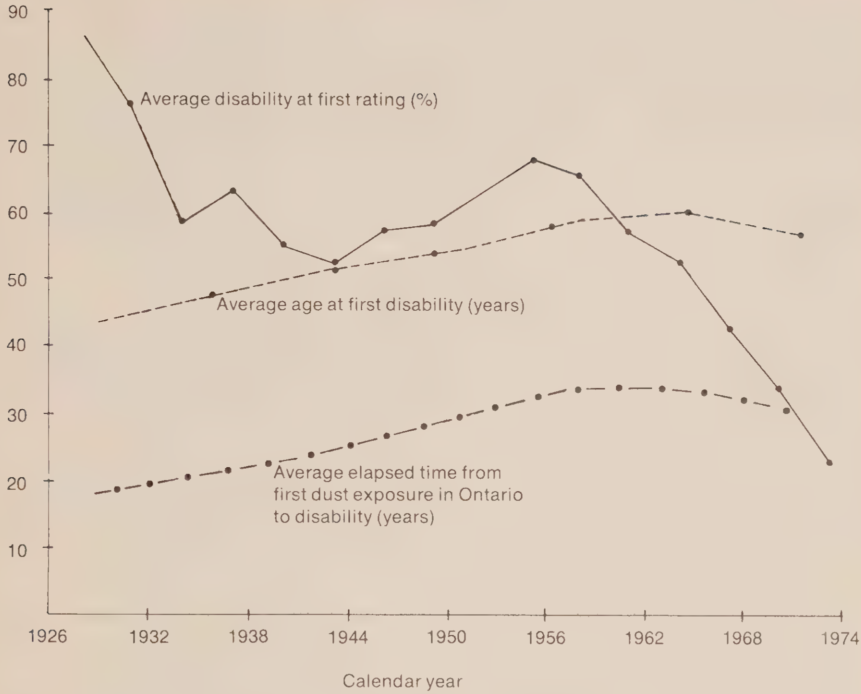


FIGURE 4 Some characteristics of silicosis cases (Source: see Figure 2)

latter figure remaining essentially unchanged from the mid-fifties through 1974. The average age at first disability has risen steadily from about forty-three years of age in 1926 to about sixty years of age in the mid-fifties and has remained nearly constant since then.

The failure of case characteristics for elapsed time to silicosis and for age at first disability to continue to rise after the mid-fifties can be correlated with the changing incidence of the disease. An average delayed incidence factor[12] for the new cases recognized in the decade 1935–44 and the subsequent decades[13] is given in the last column of Table 6. A representative average dust-exposed population to associate with 1935–44 cases was calculated by averaging the exposed population in the period 1910–29.[14] The average delayed incidence factor declined notably from 1940 to 1960, but has not declined significantly since 1960.

The lower rate of decline in the imputed incidence factor (Table 6) after 1960, the failure of the graph of age at first disability to rise after the

TABLE 6

Average delayed incidence factors by ten-year intervals

Interval of case averaging	Recognized cases per annum in interval (average N)	Workers in dust exposure in a preceding period: Period	Workers in dust exposure in a preceding period: Workers (average N)	Delayed incidence factor in cases per 1000 workers in dust exposure (average)
1935–44	45	1910–29	6,400	7.0
1945–54	39	1920–39	8,900	4.4
1955–64	31	1930–49	12,500	2.5
1965–74	36	1940–59	15,700	2.3

SOURCE: Population figures before 1928 are taken from S. McIntosh, 'A study of cases of silicosis among Ontario miners,' Ontario Mining Association, May 1962. Thereafter, figures are from records of the Workmen's Compensation Board.

mid-fifties (Figure 2), and the failure of the elapsed time from first dust exposure in Ontario to first disability to rise after the late fifties, all provide evidence that a significant change occurred in the developing pattern of silicosis.

This change was caused by two related factors. The first was the opening of the uranium mines in 1955, the effects of which will be examined later in detail. Just a few years after the opening of the mines, some workers were discovered to be suffering unexpectedly rapid radiological changes in their lungs. The first case of silicosis in a uranium miner was recognized in 1962. The second factor was a change in the policy of recognizing silicosis for purposes of compensation. This policy change is illustrated in Figure 3 in the continuing decline in the average percentage disability assigned for purposes of compensation from about 50 per cent to about 20 per cent in the years from 1955 to 1974. The designation of persons as silicotics at a lower average threshold level of clinical impairment than had been customary made it possible for the persons involved in the peculiar circumstances in the uranium mines to be kept under earlier surveillance by the Advisory Committee on Occupational Chest Diseases and enabled the Ministry of Health to develop an understanding of the special pattern of pneumoconiosis in the uranium miners.[15]

This change also extended the incentive for persons given early recognition to leave dust exposure. This incentive would derive from the fact that from 1933 to 1974 silicotics were normally not eligible, under the regulations of the Workmen's Compensation Board, to receive compensation payments until they had left dust exposure.[16] The change in compensation

policy, which began before the uranium mines opened, complicates any assessment of the historical pattern of the disease. After 1960, it is difficult in terms of disease statistics to separate effects due to a changing definition of the disease from those due to the intrinsic improvement or deterioration in the status of the disease in the industry as a whole.

SILICOSIS AND THE URANIUM MINES

The effect of the uranium mines on the evolving pattern of silicosis in Ontario will now be considered in detail. The distribution of silicosis among types of mines is not easy to determine because it is rarely possible to attribute a case definitely to any one mine. This is because of the mobility of workers, induced in part by continuing changes in the level of employment in different sectors of the mining industry, as illustrated in Table 7 for the period since the uranium mines opened. Nor can any large fraction of cases be unequivocally assigned to a single type of mine. Nevertheless, an estimate of the contribution of different types of mines to the disease can be made, as in Table 8, if it is assumed that the type of mine to which compensation is charged is that in which the worker received the dominant part of his silica-significant exposure.[17] Because of the decline in employment in gold mines and uranium mines and the diffusion of some of these workers into the growing 'other' sector, the percentages for gold and uranium in Table 8 for the period 1954–74 are considered to be understated and those for 'other' to be overstated.

TABLE 7

Distribution of workers by mining group since the opening of the uranium mines

Period	Total employment (all groups)	Employment in dust exposure (all groups)	Total employees in dust exposure (%)	Total employment by mining group (%)			
				Gold	Uranium	Silica	Other
1955–59	42,900	18,800	44	26.2	13.7	0.04	60
1960–64	41,800	18,500	44	25.8	9.2	0.02	65
1965–69	41,600	16,700	40	15.7	3.9	0.01	80.4
1970–74	41,000	16,300	40	9.0	4.1	0.20	86.7

NOTE: 'Other' means all mining other than gold, uranium, and silica groups and includes contractors. Silica group means mining and milling of quartz.

SOURCE: Mines Accident Prevention Association and Workmen's Compensation Board: Employees in Dust Exposure

TABLE 8

Sources of silicosis by mining group based on class of mine charged with compensation

Time period	Silicosis cases by mine group (%)				
	Cases (N)	Gold	Uranium	Silica	Other
Before 1954	1140	91.0	–	–	9.0
Before 1975	1812	83.3	5.1	0.4	11.2
1963–74	396	58.8	23.6	1.0	16.7

NOTE: 'Other' includes all Class 5 operations studied other than gold, uranium and silica mines; that is, nickel, copper, iron, silver, salt, nepheline syenite, asbestos, gypsum, talc, contractors. 1963–74 is the period during which all cases of silicosis charged to the uranium mines to the end of 1974 were recognized.
SOURCE: McIntyre Research Centre, *Brief to the Royal Commission on the Health and Safety of Workers in Mines*, Toronto, 1975, Appendix A, Tables 1–5, updated through 1974 at the request of the Commission.

Thus, as a qualitative judgment relative to historical levels of employment, the Commission has concluded that past dust exposure in the gold mines has generated a large fraction of the cases of silicosis found in recent years. Further, past dust exposure in the uranium mines is generating a rapidly increasing fraction of recent cases of silicosis. The growing 'other' group has been contributing a relatively small fraction of the recent cases of silicosis. The silica group, which represents a tiny fraction of mine employment, has produced a disproportionate number of silicotics, however, and deserves careful review.

The growing proportion of cases charged to the uranium mines is evidence of the central problem related to silica-laden dust in the industry today. Of the ninety-four cases of silicosis charged to the uranium mines up to the end of 1974, only one is in the Bancroft region, where the amount of free silica in the ore is 5 to 15 per cent, in contrast with 60 to 70 per cent in the Elliot Lake ores. And that case involves a miner who had nine years of dust exposure in a marble and granite quarry before spending two years in a Bancroft mine. The problem of silicosis in the uranium mines has therefore been in the Elliot Lake Mines.

The early cases of pneumoconiosis appearing in the Elliot Lake mines had unusual clinical characteristics, described by Cowle et al.[18] The most recent cases are similar to classical silicosis, except for the fact that the nodules characteristic of silicosis are more widely dispersed through the lungs. Other characteristics of the cases of silicosis charged to the uranium

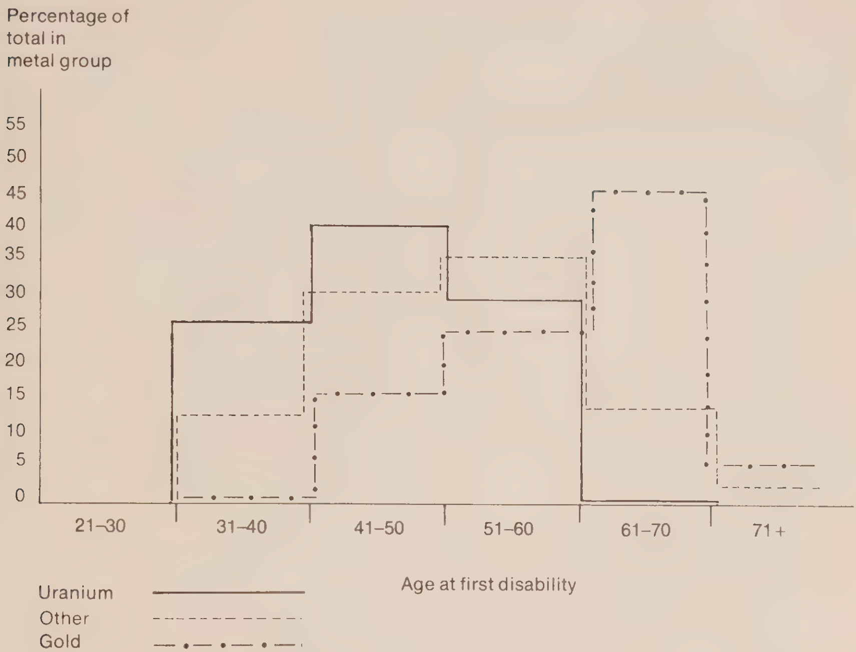


FIGURE 5 Silicosis: age distribution of cases at first disability by type of mine 1963–74 (Source: see Figure 2)

mines have been of concern. Men have been recognized as silicotics in the uranium mines at significantly younger ages than in the gold and 'other' mines. This fact is indicated in Table 9 and illustrated in greater detail in Figure 5.[19] Indeed, the average age (forty-six years) of the cases of silicosis in the uranium mines is the same as the age at recognition of persons in the gold mines about 1930. This fact implies a more rapid radiological progression of silicosis in the lungs of workers in the uranium mines.

The rate of progression from dust effects to radiological silicosis can be determined from data provided by the Workmen's Compensation Board. Plotted in Figure 6 is the percentage of the persons who, having been placed in the radiological classification 4 ('dust effects') in a given five-year period, progressed to the radiological classification 5 within five years. All persons involved in the statistics of Figure 6 have had dust exposure in Ontario only. Data are given for three groups according to whether dust exposure was in 1/ other than uranium mines (meaning *all* other than uranium,

TABLE 9

Comparative characteristics of cases of silicosis attributed to the uranium, gold, and 'other' mining groups

Metal Group	Cases (N)	Average year at entry to mining in Ontario	Average age at entry to mining in Ontario	Average age at disability	Average elapsed time in years from first Ontario exposure to disability	Exposure time (years)			Total dust exposure in Ontario metal groups other than the designated one (%)
						Metal group	Ontario	Total[a]	
Uranium	90	1954	29	46	18	10	14	17	24
Other	28	1946	26	52	27[b]	11	18[c]	19	37[c]
Gold	62	1940	30	60	31[b]	17	18[c]	19	5

NOTE: These were cases for which the disability at first rating was less than 100 per cent. All persons entered dust exposure in Ontario in or after 1930 and were recognized as silicotics in the years 1963–74 inclusive.

a Includes exposure outside Ontario

b Workers in the Gold and Other groups are often recognized as silicotics many years after leaving dust exposure and in some cases the industry.

c Of the total exposure in other Ontario metal groups, 26.8 per cent was in Elliot Lake mines.

SOURCE: Workmen's Compensation Board, Silicosis Disability Index, November, 1975, and records of the Ontario Mining Association.

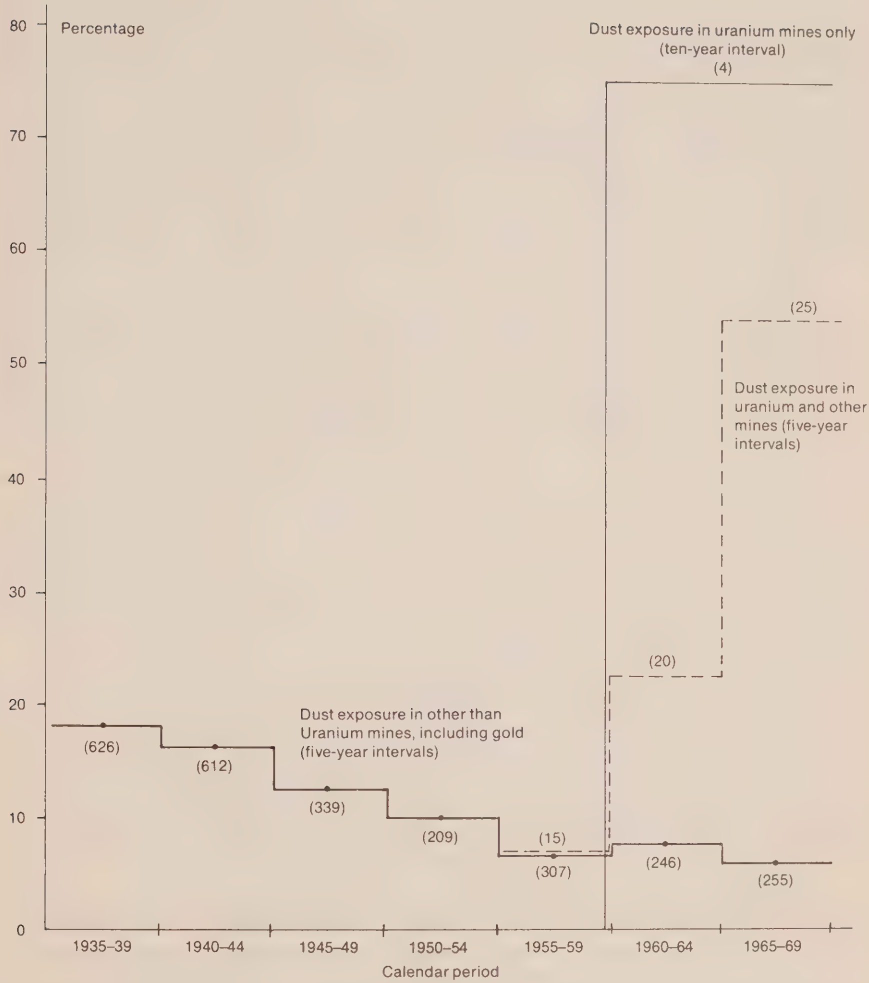


FIGURE 6 Progression rate of silicosis: percentage of persons rated Radiological 4 in designated time intervals who were rated Radiological 5 within five years, by type of mine (Note: persons with dust exposure in Ontario only; number of initial 4s in parentheses, including 4s at first examination. Source: 'Silicosis Report Programme,' Workmen's Compensation Board, November 1975, Table 15.4)

including gold, nickel, copper, etc.), 2/ uranium mines only, or 3/ uranium and other mines.

For the 'other than' group,[20] Figure 6 shows that the fraction of new class 4s identified in five-year intervals that had progressed to class 5s within five years has fallen steadily from about 18 per cent in 1935–9 to 7 per cent in 1965–9.[21] This pattern is consistent with the earlier conclusion (based on disease statistics) that the incidence of the disease was declining up to about 1960. The decline in the fraction of 4s that have gone on to 5s within five years is also believed to be a good biological indicator of the improvement in dust conditions prior to the opening of the uranium mines.[22]

In sharp contrast to the 'other than' graph in Figure 6 are those for 'uranium and other' and 'uranium only.' For the 'uranium only' group, three out of four miners with dust effects discovered between 1960 and 1969 progressed to radiological silicosis within five years. For those with 'uranium and other' exposure, the percentage of 4s progressing to 5s has been increasing and is at a very much higher level than for the 'other than uranium' group.

Figure 7 repeats the data of Figure 6, but for miners who had dust exposure outside Ontario prior to or in the course of experiencing dust exposure in Ontario. The data for the 'other than' group in the two figures is comparable, the same startling difference being apparent for the 'uranium only' and the 'uranium and other' groups.

Since the number of 4s being identified among persons with any exposure in the uranium mines has been rising through the interval 1970–4, and since the fraction of these progressing to radiological silicosis has been rising through the period 1965–9, it is reasonably clear that a significant number of new cases of silicosis will appear in future years in the population at risk. Their number cannot be predicted, but they will not all be found among current employees of the uranium mines.

The burst of silicosis in the uranium mines will have died out, relative to the historical experience in the 'other than' classification, when the fraction of new 4s found in future successive five-year periods that progress to 5s within five years falls to the levels now characteristic of the 'other than' classification.

To the end of 1974 no case of silicosis charged to the uranium mines involved a person who first entered dust exposure in Ontario in or after 1960, that is, in a fifteen-year period before 1974. This fact is encouraging, but on the other hand Table 9 shows that the average elapsed time from first dust exposure in Ontario to the recognition of silicosis among the cases

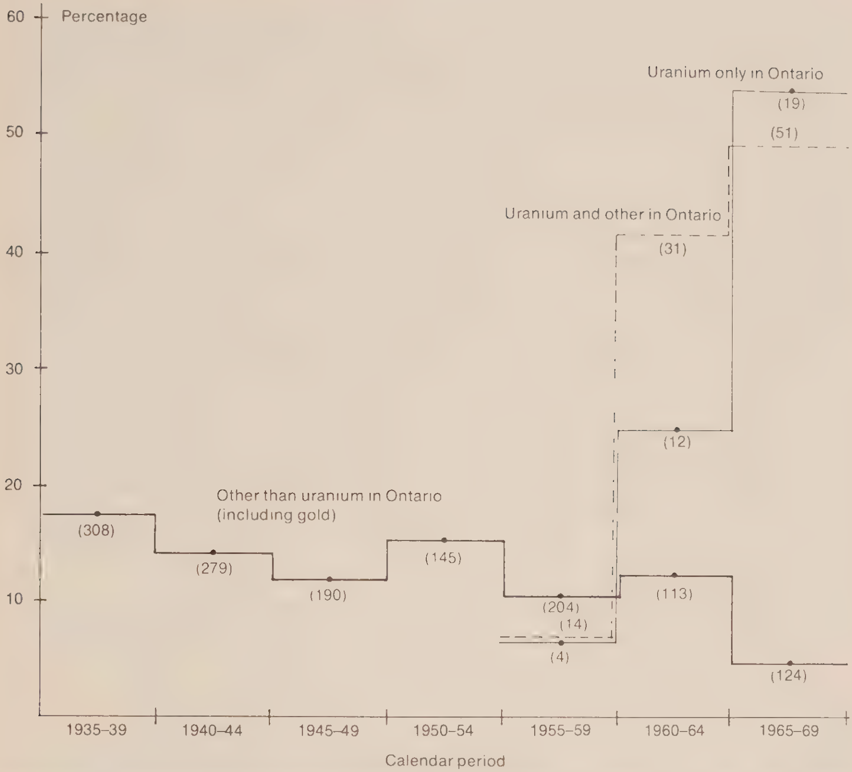


FIGURE 7 Progression rate of silicosis: same as Figure 6 but for persons with dust exposure both in and outside Ontario (Note: number of Radiological 4s at each interval includes those so categorized at a first examination; number of initial 4s in parentheses, Source: 'Silicosis Report Programme,' Workmen's Compensation Board, November 1975, Table 15.4.)

charged to the uranium mines between 1963 and 1974 was eighteen years, while that for cases charged to the gold mines was thirty-one years. Not until the elapsed time to silicosis for persons whose dominant exposure to silica dust has been in the uranium mines has increased to an average of thirty-odd years, can there be great confidence in underground mining conditions.

The observed age of the new silicotics in the uranium mines and the unusual characteristics of the related pneumoconiosis led the Advisory Committee on Occupational Chest Diseases and the Workmen's Compen-

sation Board to continue to lower the threshold of clinically assessed impairment at which compensation has been allowed. The Commission believes this to have been a humane decision, albeit one which complicates assessment of the historical pattern of the disease.

SILICOSIS AND THE RESPONSIBILITY-SYSTEM

The total number of employees in the two operating mines at Elliot Lake at the end of 1974 was 1,634 persons. Somewhat more than half of these were in characteristically dust-exposed occupations, yet this group represents a small fraction of the total number of persons who at one time or other have experienced some dust exposure in the uranium mines.[23]

The Ministry of Health in April 1975 published a report on the state of the respiratory organs of mine workers in Elliot Lake.[24] This study showed that among about one thousand dust-exposed workers employed at Elliot Lake in February and March 1974, or who had been employed as of 31 December 1973, and whose radiological records were subsequently examined, thirty-six, or 3.6 per cent of the total, had a radiological classification of silicosis and an additional fifty-three, or 5.3 per cent, had a radiological classification of 4 (dust effects).[25] The report on the respiratory system of the workers at Elliot Lake was undertaken by the Ministry of Health at the urgent request of the union locals of the United Steelworkers of America. Under the Mining Act, basic governmental responsibility for the health and safety of workers in mines has rested with the Ministry of Natural Resources (and formerly with the Department of Mines), which has published two studies on silicosis, in 1959 and 1973.[26]

During the Commission hearings it was repeatedly apparent that the workers did not have ready access to reviews of the status of occupational diseases. Nor has it been clear within the whole responsibility-system how such reviews should be generated and used. The legitimate alarm in the Elliot Lake mining community and in other mining communities that suffer at first hand the consequences of occupational disease will not be fully allayed by this Commission's report or any futher reports. But there is no reason for not providing on a regular basis to all the parties concerned, and in particular to the workers and their representatives, reviews of occupational diseases. The Commission therefore recommends:

That the Occupational Health and Safety Branch of the province conduct or have conducted and publish on a regular cycle not exceeding five years status reports on the evolution of occupational diseases among miners.

If we are to meet occupational hazards with a sensible balance between the acceptable risks and the desired economic benefits, the nature and extent of the risks manifested in the lives of working persons must be understood more openly. Workers who bear the risks, and their representatives, have in natural justice a right to know, as do the public at large. Clear independent initiative in this regard must be assigned to one authority, and that should be the Occupational Health and Safety Authority.[27] By legislative jurisdiction and administrative practice, this agency, in its present form as the Occupational Health Protection Branch in the Ministry of Health, has been denied the opportunity and resources freely to perform the above task and many related ones. Because the burst of silicosis related to the Elliot Lake uranium mines is in the early stages of its evolution, the Commission further recommends:

That the radiological status of silicosis in the dust-exposed population currently employed in the Elliot Lake uranium mines and all other uranium mines be reviewed by the Occupational Health and Safety Branch on a biennial basis for a period of at least ten years,

That the radiological status of silicosis among the persons on record on the Uranium Nominal Roll be reviewed on a biennial basis for a period of at least ten years.

Recommendations on work adjustment and workmen's compensation pertaining to workers currently employed in the uranium mines and to persons on the Uranium Nominal Roll are presented later in this chapter.

THE ROOTS OF THE PROBLEMS OF THE ELLIOT LAKE URANIUM MINERS

The burst of silicosis associated with the Elliot Lake uranium mines was partly caused by the precipitate manner in which these mines in highly siliceous ores were developed (and shut down) and by the work environments that resulted. The effectiveness of the responsibility-system in dealing with the problem of dust in these and other mines will be examined in the following sections of this report.

Because of the long latency factor in silicosis it is important at this point to have a picture of the historical development of the situation in the uranium mines. Between 1954 and 1958 twelve mines came into regular operation in the Elliot Lake region and four in the Bancroft region. Total employment at Elliot Lake rose from about five hundred at the end of 1954

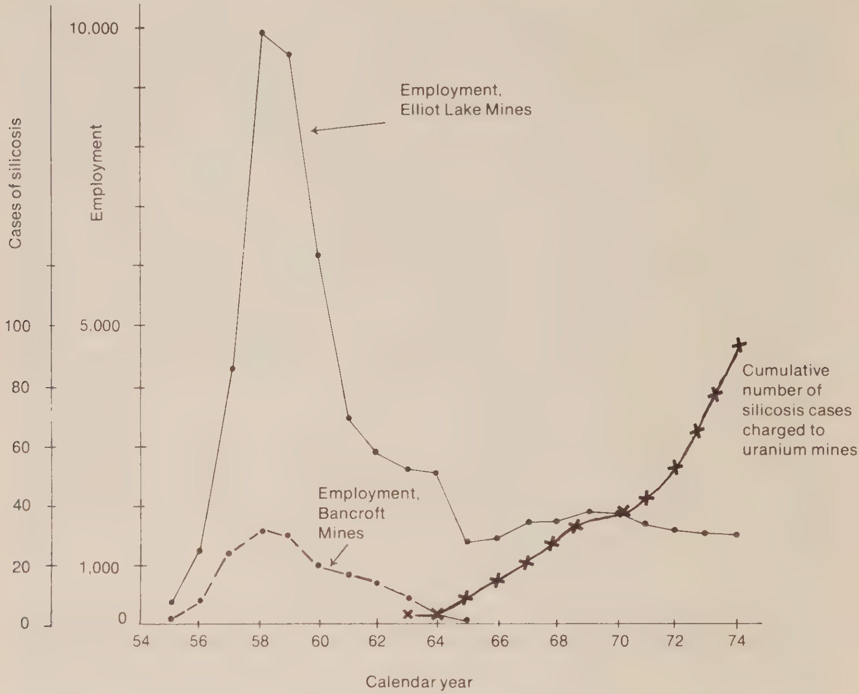


FIGURE 8 Employment in uranium mines and cumulative number of cases of silicosis charged to these mines (Source: Records of the Ontario Mining Association and the McIntyre Research Foundation)

to ten thousand at the end of 1958. Four years later it had fallen to under three thousand; by 1973 only two uranium mines were operating, with a total employment of some sixteen hundred persons. These trends are illustrated in Figure 8, which also presents the cumulative number of silicosis cases charged against these mines. The mines at Elliot Lake now anticipate a period of substantial growth. New uranium mines are opening at Agnew Lake and mines in the Bancroft area will reopen shortly.[28] Cause for concern about environmental conditions remains.

In May 1958, following representations from the United Steelworkers, the Department of Mines established a Special Committee to study the accident situation and mining practices in the Elliot Lake District.[29] Its report provides a statistical, pictorial, and interpretive account of the early phases of development of these mines. The following quotation from that

report, together with the graphs in Figure 8, will serve as a commentary upon the early Elliot Lake development:

A Crown company, Eldorado Mining and Refining Limited, then the sole purchaser of uranium oxide and other nuclear materials in Canada, entered into contracts, at stated prices, with those companies showing a production potential for the purchase of uranium oxide, aggregating over $1,000,000,000 in value.

The contracts are valid until 1962 and in some cases into 1963. They permitted the financing and equipping of the mines for rates of production that would meet their contracted quotas. They also gave the companies an assured income for the lives of the contracts but left the future beyond 1962–63 very uncertain.

The stocks of uranium oxide at the disposal of the western world and for annual requirements are, of necessity, classified information. Those responsible for such matters have contracted for the above supplies from the Elliot Lake mines. Under the circumstances, this was one of the few ways in which the responsibility for such a gigantic procurement, together with the complex problems and risks involved, could be passed from government to private enterprise with which the general public could be associated. In doing so, however, government has protected itself to the extent that the contracts not only call for the total commitments by 1962–63 but further call for deliveries to commence on specified dates.

Thus, if a company had failed to meet the delivery requirement, there was a risk of having the contract cancelled. Also, the financing arrangements of many of the companies were such that operating revenues were necessary to meet the interest charges on borrowed capital. Both of these factors introduced a time incentive from which, in the early stages at least, a pressure on production inevitably followed.[30]

Of the problems of health and safety that have emerged out of the Elliot Lake situation, dust and radiation are two that are central to this report. The problem of dust will now be examined in the context of the industry as a whole.

DUST

The labour unions have vehemently made many allegations about dust conditions and about the practices for monitoring them. To analyse the problem it is useful to set down the following questions: Who determines what levels of exposure at the workplace are acceptable? What are these levels? How are they determined? Who monitors actual dust conditions, when and how? Who has the responsibility to audit measurements and to inspect conditions? What is the record of compliance?

When viewed in terms of these questions, the allegations of the unions, particularly those regarding Elliot Lake, constitute a charge that the agen-

cies possessing authority to control dust conditions have failed to exercise their responsibilities in an effective, open, and accountable manner. It is central to the remainder of this report to understand why such a charge might be made.

Under Part IX[31] of the Mining Act, on health and safety in mines and plants, primary responsibility for compliance is placed upon the owner:

169(1) The owner or agent of an operating mine or plant shall appoint a manager who is responsible for the control, management and direction of the mine or plant.
(2) The owner or agent shall provide the manager of a mine or plant with the necessary means and shall afford him every facility for complying with this Part ...
(6) Except as to any provisions that the chief engineer has directed are not applicable thereto, the manager of the mine or plant shall take all necessary and reasonable measures to enforce the provisions of this Part and to ensure that they are observed by every employee of the mine or plant, and every supervisor shall take all necessary and reasonable measures to enforce the requirements of all such provisions as are applicable to the work over which he has supervision and to ensure that they are observed by the persons under his charge and direction.

Representative requirements concerning dust are as follows:

213(1) The ventilation in every mine shall be such that the air in all of its workings which are in use shall be free from dangerous amounts of noxious impurities and shall contain sufficient oxygen to obviate danger to the health of anyone employed in the mine.
213(10) Every place in a mine where drilling, blasting, or other operations produce dust in dangerous quantities shall be adequately supplied at all times with clean water under pressure or other approved appliance for laying, removing or controlling dust.
213(12a) A fresh air supply independent of the air supplied to any machine or drill used therein shall be provided ... in every raise ...
214(1) There shall be provided a positive supply of fresh air into, and provision for the removal of vitiated air from, a plant building that is sufficient to keep the air reasonably pure and to render harmless so far as is reasonably practicable, all gases, vapours, dusts or other impurities that are likely to endanger the safety of any person therein.
214(4) There shall be provided and used, where a process is carried on that produces a gas, vapour, dust or other impurity that is likely to be inhaled to an injurious extent by persons in the plant building, such mechanical means satisfactory to an engineer, as are capable of (*a*) preventing, as far as is reasonably practicable such inhalation; (*b*) effectively carrying off and disposing such gases, vapours or dusts; and (*c*) preventing, as far as is reasonably practicable, the recirculation and re-entry of air containing such impurities.

This legislation gives to the owner-manager the freedom to achieve the required ends to the degree and by the means judged by him to be suitable. This judgment is subject to review by the engineers (mining inspectors) of the Mines Engineering Branch of the Ministry of Natural Resources, who are assigned the following broad powers and duties:

610(1) It is the duty of the engineer and he has power: (*a*) to make such examination and inquiry as he deems necessary to ascertain whether this Act is complied with, and to give notice in writing to the owner, agent or manager of any particulars in which he considers the mine or plant or any part thereof, or any matter, thing or practice to be dangerous or defective or contrary to this Act, and to require the same to be remedied within the time named in the notice; (*b*) to enter, inspect and examine any mine or plant or any part thereof at any reasonable time by day or night, but so as not to unnecessarily impede or obstruct the working of the mine or plant; (*c*) to order the immediate cessation of work in and the departure of all persons from any mine or plant or part thereof that he considers unsafe, or to allow persons to continue to work therein on such precautions being taken as he deems necessary; and (*d*) to exercise such other powers as he deems necessary for ensuring the health and safety of miners and all other persons employed in or about mines, plants, pits, quarries or other works.

As a body of law the Mining Act is unusual in that there is no associated set of regulations on health and safety passed by order in council. An item that would be a regulation under, for example, the Industrial Safety Act is made part of the Mining Act and passed in detail by the legislature. However, the chief engineer of the Mines Engineering Branch has from time to time issued 'codes of requirements' on such areas as the measurement of dust and radiation, allowable radiation levels, and ventilation for diesel engines underground. These codes have been arrived at after consultation with the industry and, as deemed appropriate, with the Ministry of Health and other agencies. They constitute an interpretation of general requirements of the Mining Act in the form of specific practices acceptable to the chief engineer and to the industry.

The legal framework for health and safety in the mines as sketched above has resulted in strong reliance being placed by the government on the self-regulatory initiatives of industry through individual companies and collectively through the educational activities and moral suasion of the Mines Accident Prevention Association.[32] The Mines Engineering Branch has fulfilled the dual role of inspecting mines and plants in accordance with the provisions of the Mining Act and through consultation establishing technical standards and codes of requirements for the industry. Such consultation between this branch and the industry has come to be seen by

the unions as, at best, accommodation of interests[33] and, at worst, collusion.

The Mines Engineering Branch and the industry itself are the agencies responsible under existing law for health and safety conditions in mines and in particular for dust conditions. The response of the labour unions, especially to the problems at Elliot Lake, becomes fully understandable when it is realized that there has been no code of requirements specifying allowable dust levels, that until January 1975 workers and their representatives have not been informed on an industry-wide basis about dust conditions, and that the public annual reports of the Mines Engineering Branch and of the Mines Accident Prevention Association have not provided critical reviews of dust conditions. The unions have perceived the responsibility-system to be closed and not accountable.

How effective, therefore, has this system, with its strong self-regulatory nature, been in controlling dust conditions?

Dust and its measurement

Dust is measured for two basic reasons: 1/ to determine the levels that result from mining procedures, work practices, and the conditions of ventilation at the workplace, the objective being to achieve engineering control of the generation and dispersal of dust; 2/ to obtain quantitative data on human exposure that will permit epidemiological study of the relation of human response to dose, with the goal of providing a quantitative basis for the setting of health preserving dust standards.

The hazard of dust is related to particle size, surface area, mass, and chemical composition, and to particle concentration. Mineral dust is a major constituent of mine aerosols, but the latter may also contain oil mist from drills, particulates from diesel exhausts, and radioactive particles deriving from radon gas emanating from rock faces and broken rock. The hazard to the lungs is produced by inhalation of particles from about 10 microns in size to less than 1 micron in diameter.[34] The larger particles are trapped in the nasal passages and trachea; the mid-range of particles may be deposited in the bronchioles and alveolar sacs of the lungs; the smallest particles may be breathed in and out.[35] Respirable dust in the size range of microns is invisible in ordinary light and remains suspended in air for long periods.[36] Respirably hazardous dust therefore tends to build up in the air at any dust-generating process such as drilling, slushing, mucking, dumping, and crushing.

There are many different instruments for measuring dust.[37] The instrument in use on an industry-wide basis in Ontario[38] is the konimeter,

adapted from South African practice of the 1920s. This instrument sucks in through a small orifice a five-cubic-centimetre volume of dust laden air. This process occurs in one-fifth of a second, so that the instrument takes a 'snap' sample. The dust in the sample of air is deposited on an adhesive layer on a glass plate. After a heating and acid treatment the residue of dust particles on the glass plate is counted visually under a microscope[39] and expressed as a number of particles per cubic centimetre (PPCC). The treatment procedure removes combustibles such as diesel soot and acid soluble minerals such as carbonates. Free silica and various silicates are among the residue of particles counted. An electronic optical scanner[40] was developed by the Mines Accident Prevention Association in the 1960s and made available to the industry for standardized reading of glass slides at its North Bay field station in 1969.

A standard procedure has been developed for dust measurement at the workplace.[41] This calls for three snap samples to be taken in the breathing zone of the worker down wind from a mining operation, such as drilling, which is to be taking place. A single snap sample of the air entering and leaving the workplace is also taken.

The konimeter is a 'spot' sampler in both place and time. Information presented to the Commission[42] reveals that if a konimeter measurement is made at half-hour intervals during a working shift at a given workplace with operations starting and stopping, variations on the order of 5 : 1 in the readings are encountered. The instrument and the standard procedures of sampling used with it are therefore unsuitable for determing the total exposure to dust to which a worker may be subjected over a working shift. But the konimeter is useful for engineering control as an indicator of comparative dust levels being encountered. For this purpose it is necessary to average sets of readings taken at similar workplaces near such operations as drilling, mucking, and crushing. When konimeter spot samples are averaged over a class of workplaces in a mine, over a whole mine, and across groups of mines of a given type, qualitatively comparative dust records are obtained.

The representatives of workers expressed before the Commission deep concern about the accuracy and adequacy of the dust-sampling procedures used. Before January 1975, workers were not informed on an industry-wide basis what the readings were, what the accepted procedures of measurement were, or what purpose the readings served. This fact reflected a general lack of communication from management to workers on matters that are of legitimate concern to workers. The paternalistic attitudes of the past which appear to remain in parts of the industry are not, in the

Commission's view, acceptable. It is therefore recommended:

That the functional purpose, measuring procedures, and measured results relating to all environmental monitoring at the workplace be made known in understandable language to all affected workers and their representatives by the employer and as appropriate by the Mine Inspection Branch.

Subsequent recommendations will deal in more detail with how the workers and their representatives may participate in achieving a wider understanding of environmental conditions, and of their inescapable involvement in influencing these conditions through their own work practices.

DUST AND THE RESPONSIBILITY-SYSTEM

There were no systematic industry-wide measurements of dust before the opening of the uranium mines. From the mid-twenties the konimeter was used in gold mines for engineering control purposes to recognize exceptional dust conditions. After the Mines Accident Prevention Association was established in 1930, concerted efforts to deal with dust conditions began, and by 1954, when the uranium mines opened, initial dust guidelines had been formulated by the Association: 'Through the years we have come to appreciate that, in our case, konimeter counts of the order of 100 to 300 particles per cubic centimetre are good; those of the order of 500 to 700 or 800 are fair, only; while those in excess of 1000 PPCC are poor.'[43] The selection of these levels was based on 'best practice' in Ontario gold mines, on a knowledge of then current South African practice, and on the Ontario Mining Association's study of the developing record of silicosis. These guidelines, with the implication that they were suitable for percentages of quartz encountered in gold mines, were in use by the MAPAO when the uranium mines opened.

The guidelines and their subsequent variations to date had, and have, no legal validity as dust standards. Under the Mining Act no statutory standards for dust have been issued. It is therefore important to understand that there has been no question of legal compliance with stipulated standards. On a collective basis, the industry has had guidelines, which were tacitly accepted by the Department of Mines as a basis for guiding the Mines Engineering Branch in its interventions with management.

In matters of health and safety in the mines, an important principle of the Ontario Mining Association, as reflected in the work of the Mines Accident

Prevention Association, has been that self-regulation is preferable to intervention by government. The Commission believes the principle of self-regulation is sound, but the associated issue of accountability of both industry and government must be made clear.

It has been noted that no systematic industry-wide dust measurements were made prior to the opening of the uranium mines in the mid-fifties. However, concern about potential radiation and related dust hazards in the developing uranium mines led the then Department of Mines and the Ontario Mining Association to an agreement[44] for an initial survey[45] of conditions to be undertaken by the Mines Accident Prevention Association. The issue of accountability for the validity of the measurements was raised by a spokesman for the industry who 'asked the question that in the event a question is later raised in the House or in another manner, to the Department, as to the actual situation existing, is the Department going to be satisfied with the results and be able to back up the work even though it is carried out by the Association.'[46] The spokesman for the Department 'stated that his Department would have full confidence in the work of the Association and would do its best to support the work in public.'[47]

In March 1957, undoubtedly in response to the evidence of the first survey of conditions, the chief engineer of the Mines Engineering Branch issued a code of requirements for the measurement of radiation and dust levels on a quarterly basis in the uranium mines.[48] No dust or radiation standards were included. In December 1957 the Department of Mines commissioned Dr J.F. Paterson to study the problem of silicosis in the mining industry and his report was submitted in June 1959.[49]

In response to these initiatives by the government, the directors of the Ontario Mining Association recommended to its members in the Mines Accident Prevention Association the adoption of a voluntary code[50] of dust sampling on a semi-annual basis for all mines other than uranium, salt, and asbestos.[51] The Mines Engineering Branch welcomed this initiative. While not all mines immediately participated in this voluntary system, it came into being and remains in regular operation. The results of these voluntary surveys and of the surveys required in the uranium mines constitute the system-wide record of dust conditions in the industry. These will shortly be reviewed.

Underlying the foregoing sequence of events are the important issues of accountability and openness, which were revealed by a senior spokesman for the labour unions when he stated before the Commission: 'We believe if there were any independent data on dusts and other hazards in mines it would prove that the MAPAO has not been an effective force for safety and

TABLE 10

Early dust levels in the uranium mines

Date of report	Mine	State of development	Location of samples	Konimeter average in PPCC	Number of samples
January 1956	Faraday (Bancroft)	Underground development	Underground	718	48
January 1956	Bicroft (Bancroft)	Underground development	Underground	541	63
March 1956	Pronto (Elliot Lake)	Producing	Headings and raises	890	63
			Stopes	556	45
			Surface crushing	689	48
June 1956	Quirke, Algom (Elliot Lake)	Underground development	Headings and raises	776	108
			Travelways and airways	807	45
January 1957	Nordic, Algom (Elliot Lake)	Underground development	Headings and raises	959	105
			Travelways and airways	768	96

SOURCE: Mines Accident Prevention Association of Ontario, Surveys of uranium mines 1955–7; For complete reference see note 45.

that all the statistics based on MAPAO guidelines that its members compiled are worthless.'[52] The Commission has no evidence to cast doubt on the general validity of the measurements of dust compiled by the industry, as required by the code for the uranium mines, and for other mines voluntarily. But as a matter of principle it is recommended:

That the Mines Inspection Branch within the Occupational Health and Safety Authority conduct annually, or have conducted by an independent agency, sample measurements at representative workplaces of all environmental quantities whose values are audited by the Authority in carrying out its role;

That the Occupational Health and Safety Authority publish at least biennially a critical review of its appraisal of environmental conditions at the workplaces in the mines and mineral plants.

Self-regulation is a valuable and desirable principle, but to be properly effective there must be more open accountability on the record. There has not been publicly available a record of dust conditions in the mines.

The record of dust conditions

The dust conditions observed during the early development of representative uranium mines at Bancroft and Elliot Lake are summarized in Table 10. It will be recalled that whereas the free silica in the ores at Bancroft is in the range 5 to 15 per cent, in the ores at Elliot Lake it is 60 to 70 per cent.

The historical evolution of underground mine average dust levels by class of mine in the industry as a whole is shown in Figure 9.[53] This figure shows that over the historical period of system-wide observation, dust levels have decreased in each class of mine by a factor of about two, the major decrease having occurred in the period 1958 to 1965. In reflecting upon these data it is important to relate them to the guidelines of the Mines Accident Prevention Association then current. In the early period, until about 1960, the initial guidelines developed from experience with gold mines prevailed. Nickel mines, with their low percentage of free silica in the ore, were not considered to present a major silicosis hazard. However, the uranium mines were a problem, and the guideline for 'good' dust conditions of 100 to 300 PPCC was considered by the engineering staff of the Mines Accident Prevention Association to be applicable.[54] In the period 1960 to 1969, the early 'gold' guideline was elaborated to provide dust guidelines based on the percentage of quartz (or free silica) in total dust.[55] These guidelines were first published in 1969.[56]

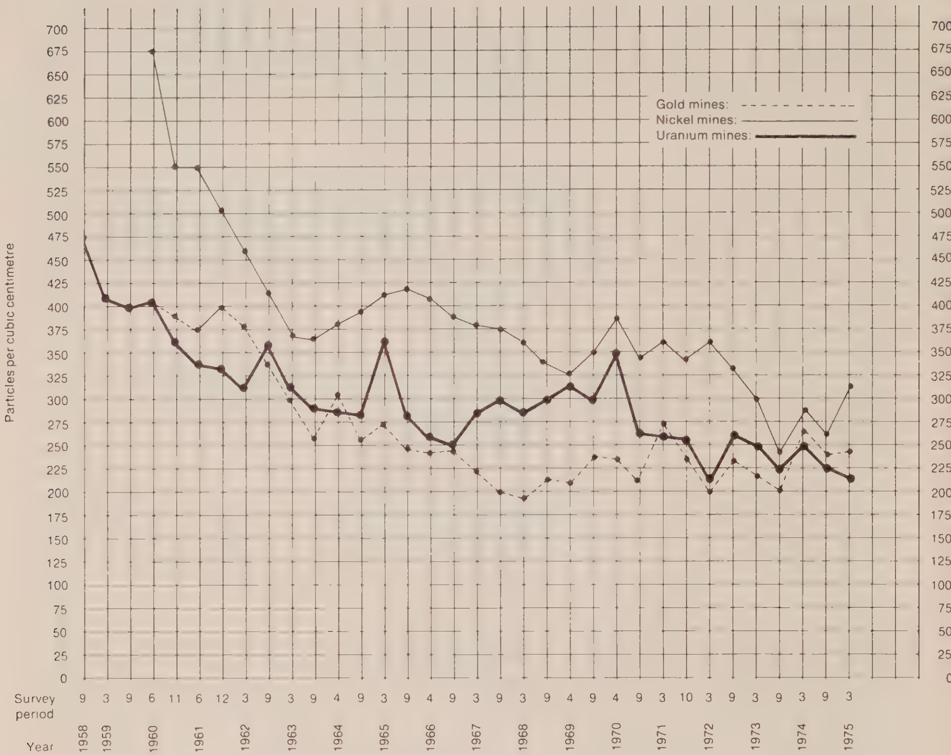


FIGURE 9 Average underground dust conditions for gold, nickel, and uranium mines 1958–75 (Note: the uranium mines were surveyed four times a year between 1959 and 1961 and three times a year between 1962 and 1964. The first and third surveys of these sets have been used for this comparison. Source: MAPAO semi-annual surveys of dust conditions)

Table 11 reviews average dust conditions in the nickel, gold and uranium mines in terms of the guidelines of the Mines Accident Prevention Association current as of April 1975. Tables D.2 through D.4 provide a basis for judging conditions at particular classes of workplaces as contrasted with mine averages. For mine averages it is apparent that the nickel mines are

TABLE 11

Some characteristics of underground dust conditions in Ontario mines

Type of mine	Average dust level[a] in PPCC 1st half 1960	Average dust level[a] in PPCC 1st half 1975	Quartz in total dust (average %)[b]	MAPAO guideline (1969) in PPCC by percentage of quartz in total dust[c]
Nickel	680	310	Up to 10[d]	500 (up to 10% quartz)
Gold	400	250	15 to 35	300 (10 to 30% quartz)
Uranium	400	220	60 to 70[e]	200 (over 30% quartz)

SOURCE: Mines Accident Prevention Association of Ontario, *Semi-Annual Surveys of Dust Conditions*, 1958–1975

a From Figure 9 (rounded to nearest 10)

b Log of Analysis of Aerial Dusts from Ontario Mines, MAPAO (1935–1975) and First Surveys of the Uranium Mines.

c MAPAO, *Airborne Contaminants, Mining, Milling, Smelting and Refining*, 1st ed., 1969

d Sudbury Basin

e Elliot Lake Mines

well below the current guidelines, the gold mines are below the guideline, and the uranium mines continue to be above the guideline.

When the guidelines are applied to classes of workplaces as listed in Tables D.2 through D.4 for the period 1973–5 the nickel mines are observed to meet the guideline at all recorded types of workplace, the gold mines substantially meet the guidelines in all but one category, and the uranium mines are above in eight out of nine categories. In these circumstances anything less than the most rigorous attention to the reduction of dust in the uranium mines must be deemed unacceptable, and recommendations follow on this matter. Further, it is important that guidelines not be understood to be limits which become by precedent the tolerated average levels. The objective must be the lowest practicable levels of dust.

The response of the industry to self-regulation and to the actions of government is reflected in the foregoing record of dust conditions and dust guidelines. The Commission has studied records of the work of the Ontario Mining Association, the Mines Accident Prevention Association, and the Mines Engineering Branch through the period 1955 to 1975. Since these institutions have been the subject of sharp criticism by the labour unions, some assessment of their actions in relation to dust control is important.

The record shows that it was the policy of the Ontario Mining Association to have the technical staff of the Mines Accident Prevention Association work assiduously to educate and to guide companies in the control of dust by auditing company operations and providing technical information. Critical annual reviews of dust conditions within the industry have been circulated to member companies.[57] Within the context of its dependence on the Ontario Mining Association for policy direction and its legal charter under the Workmen's Compensation Act, the Mines Accident Prevention Association has attempted to exercise moral suasion based on collective industrial self-interest. It has been clearly perceived by the industry that want of self-regulation would lead to greater intervention by government.

The self-regulatory approach to problems of health and safety for workers, whatever the quality of its general performance, has a fundamental weakness or incompleteness. Not all management in Ontario mines have seen, or are likely to see, collective interest as corresponding to self-interest. A well-informed Mines Inspection Authority is necessary on several grounds, but in particular to discern and to deal bluntly with this situation.

Since self-regulation is important, but a greater measure of openness is necessary to justify public confidence in this process, it is recommended:

That the legal framework for the health and safety of workers in mines continue to recognize the importance of a significant component of collective self-regulation by industry as a whole achieved through a Mines Health and Safety Association.[58]

The Mines Engineering Branch has had the responsibility of determining whether the management of mines has complied with the provisions in the Mining Act concerning dust and the health of workers. It has been indicated that the provisions of the Act related to dust are general and not susceptible of precise legal interpretation. The Mines Engineering Branch has issued no code of requirements for dust levels; for underground conditions it has relied on the dust guidelines of the Mines Accident Prevention Association.

Within this limited framework, the record shows that inspectors were not negligent in auditing dust records, inspecting mines, and issuing letters of instruction to the managers of uranium mines and of other mines under Section 610(1)(a) of the Mining Act. Yet two factors have limited the effectiveness of work in the field. The Mines Engineering Branch has not

had adequate resources to fulfil the responsibilities assigned to it. It has lacked adequate staff and independent expertise in dust control and ventilation. Further, in the absence of statutory standards for dust a mines inspectorate is limited in the effectiveness with which it can demand compliance with qualitatively defined environmental requirements characteristic of the Mining Act. Its effectiveness depends strongly on the clarity with which the responsible ministry makes known its expectations of industry. When that ministry has the role both of promoting the development of the industry and of protecting the health and safety of workers, failure to act is inevitably seen as accommodation of interests. In the Commission's view there has been on more than one occasion unjustified complacency at the policy-making level both in government and the industry.

On the basis of the foregoing review it is apparent that collective industrial self-regulation and mines inspection as these then existed were not strong enough to meet the challenge presented by the explosive initial development of the uranium deposits. Attention to industrial development and to corporate economic risks dominated concern for the health of workers. The existing responsibility-system has gradually succeeded in bringing the average dust conditions in the industry close to or below the guidelines in use. Because of the general improvement in dust conditions the rate of appearance of silicosis in the groups other than the uranium mines may be expected to continue to decline. But for a decade or more the consequences of the early conditions in the uranium mines will continue to be evident in the distinctive burst of silicosis that has been identified. Current conditions among persons on the Uranium Nominal Roll deserve further discussion.

The ongoing control of dust

There are two steps that I believe should be taken with the intent of ensuring the continued improvement of dust conditions where these are unsatisfactory. These are the issuance of codes of practice on ventilation and on work practices; and the establishment of statutory standards for the exposure of workers to dust.

The industry has long been aware of the methods available to prevent fine dust from becoming airborne, to confine and collect dust that does become airborne, and to dilute and sweep out the residual dust by main and auxiliary ventilation. I have no doubt that good practice is followed at many workplaces. However, the following quotations from a recent survey of

underground air conditions by the Mines Accident Prevention Association is symptomatic of the fact that what is known is not always practised.[59] The investigations of the Commission have confirmed that the situations referred to are of long standing and are not peculiar to the uranium mines.

Drilling
Air-water blasts are mandatory under the Mining Act in headings and raises, the use of this device is recommended in stopes as well, yet there is a large number reporting that it is not used ... The air-water blast is a first line defense in control of dust concentration, and is of utmost importance in conditioning broken rock to reduce ventilation volumes required to dilute dust and gas concentrations.

The removal of handvalves in water lines at machines equipped with automatic backheads eliminates the temptation to collar dry. While many of the drill machines having hand valves in the water lines are stopers, almost one half of the mines report that handvalves have been retained at all machines ...

Handling Muck
There is a continuing need for more effective applications of water to condition the muck prior to handling. The number of mines reporting on the use of intermittent sprays is disappointingly small, those using the preferred continuous sprays even more so ...

Ventilation
Auxiliary ventilation continues to be used extensively in working places lacking through airflow. The number of headings and stopes ventilated by auxiliary means decreased slightly over that of a year ago, which probably accounts for the number of these locations that report airflows too slow to measure. It is gratifying to note that the number of raises ventilated has increased ...

The foregoing review includes the following statement:

Reduction of dust concentration to acceptable levels requires constant and complete cooperation of all concerned. Proper conditioning of broken rock (with water), adequate dilution volumes of fresh air, adequate enclosures with sufficient exhaust volumes are all necessary to provide a clean healthy work environment. The effectiveness of any system is a function of how closely actual operating conditions meet design considerations. Supervisors and ventilation personnel must be prepared to explain the basic principles involved to operating personnel if maximum benefits are to obtain from existing installations ...

Getting the muck out involves continual judgment by all those engaged as to what constitutes effective work practices. Any natural or induced propensity of the worker to neglect good work practices must be met by

effective training and supervision. In turn the shift boss and related ventilation staff must be working under clear policy direction from senior management. Production with safety and health poses a continuous challenge at every level. The Commission believes that codes of practice[60] should be prepared to guide all parties and therefore recommends:

That the Mines Inspection Branch within the Occupational Health and Safety Authority, in consultation with industry and the representatives of workers, prepare, under clearly defined statutory authority, Codes of Practice applicable to all mines relating to: 1 / the prevention and confinement of dust at each distinctive class of workplace; 2 / the provision of ventilation in the breathing zone of workers that is effective for purposes of protecting health at each distinctive class of workplace (including vehicles);

That the management of each mining operation or appropriate part thereof be required under clearly defined statutory authority to prepare and keep updated a Scheme of Practice for implementing the foregoing codes;[61]

That the management be required to appoint a competent person to supervise the over-all operation of the scheme.

The documentary basis for such schemes is implicitly present in the policies and procedures of each mining operation. It is being recommended that these be compiled into a local manual of practice explicitly concerned with the interplay between production, safety, and health, and it is essential that responsibility for carrying out the scheme should be clearly assigned. In underground mining it is singularly important that the shift boss be conversant with the scheme of practice as it applies to day-to-day work and with his responsibilities under it. Such a plan is intended to provide a manual for the guidance of workers and supervision, a point of reference for the auditing of operations by mine inspectors and for the promotion of understanding of underlying problems between management and the representatives of workers.

DUST STANDARDS

Industry-wide dust control in Ontario mines continues to be based on the konimeter. Such measurements, however, are not indicative of an individual's personal exposure to dust over a working shift and are thus inadequate.

The industry has expressed confidence that adherence to its dust guidelines will lead to the continuing decline of silicosis as a disease. The radiological progression data presented support this view for mines other than the Elliot Lake uranium mines. The historical growth of the proportion of the dust-exposed population working with ores having lower free-silica content than those of gold and uranium is a significant circumstantial factor in favour of a decline of the disease in the industry as a whole. However, individual workers have the right to reasonable assurance that their dust exposure at work is within standards designed to protect their health. A low incidence of disease in the whole population of dust-exposed persons may correspond to a much higher incidence among workers engaged in 'worst case' jobs. The Commission therefore recommends:

That the Occupational Health and Safety Authority establish by regulation a dust standard for personal exposure to free silica in mine and plant aerosols based on a time-weighted average of respirable dust intensity over a working shift and a stipulated lifetime period of exposure.

That the dust standard for time-weighted average exposure be established on a statutory basis.

The extent of personal exposure to dust during a working shift can be indicated by an instrument that continuously draws dust-laden air through a porous membrane on which the dust collects. By the nature of its design, the instrument can select the respirable range of particle sizes. With respect to silicosis the most commonly accepted measure of the pulmonary hazard of dust-laden air is the mass of respirable free silica, often expressed in milligrams per cubic metre of air.

The introduction of a statutory dust standard must be undertaken with meticulous care.[62] The promulgation of a numerical standard alone is pointless. Before a standard can become effective for the protection of health all of the following points must be dealt with, some of them involving codes of practice and others requiring regulations:

1 the choice of the property of respirable dust to be used as an indicator of exposure and the specification of the means for measuring it;
2 the specification of the selection characteristic for aerosol particles of different size (to establish the definition of respirable dust);
3 the adoption of a commercially available instrument technology[63] capable of collecting dust over a working shift with the necessary accuracy and reliability under field conditions;
4 an approved and readily accessible service for the accurate assessment

of instrument readings and for the regular calibration of instruments;
5 a code of practice for the use and maintenance of instruments;
6 regulations identifying the persons considered to be in dust exposure;
7 regulations governing the frequency and conditions of regular sampling;
8 regulations governing the keeping and reporting of dust and related occupational records of individuals;
9 regulations defining how 7 and 8 are to be extended when the current samples at a given workplace or class of workplace are not in compliance with the standard;
10 operative understanding of, and confidence in, the purposes of the monitoring program on the part of all affected parties.

Over a period of years the Mines Accident Prevention Association in co-operation with the Canada Centre for Mineral and Energy Technology and with the assistance of the McIntyre Research Foundation has been conducting experimental studies on the measurement of respirable dust on a full-shift basis in representative Ontario mines.[64] Experimental results of recent gravimetric measurements are summarized in Table 12. The Commission believes that this work, using the x-ray method of measuring the mass of free silica in the total mass of dust collected over a full shift, establishes the feasibility of introducing a personal dust standard in Ontario mines. There are practical problems of achieving all of the conditions for effectiveness that have been listed, but the existence of these problems is not an excuse for delay in resolving them.

It is proposed that a statutory standard for dust exposure be attained in two stages. Therefore, it is first recommended:

That the Occupational Health and Safety Authority immediately establish by regulation an interim threshold limit value (TLV) for the mass of respirable free silica in milligrams per cubic metre.

That the interim TLV have the status accorded by the Occupational Health and Safety Authority to threshold limit values as issued by the American Conference of Governmental Industrial Hygienists.[65]

That the Occupational Health and Safety Branch prepare a code of requirements for the gravimetric measurement of dust in all mines suited to determining personal exposure to dust.

That all steps necessary to render effective a gravimetric standard of dust measurement including those listed herein be implemented immediately.

It is suggested that the initial code of requirements for gravimetric

TABLE 12

Experimental gravimetric dust measurements underground in four Ontario mines

Type of mine	Samples (N)	Average mg/m³ of free silica	Samples over 0.1 mg/m³ (N)
Nickel	151	0.03	4
Gold			
Mine A	231	0.06	45
Mine B	119	0.13	53
Uranium	165	0.11	71

SOURCE: Mines Accident Prevention Association of Ontario, *Gravimetric Sampling in Metal Mines*, May 1975. Airflow 2.1 litres/minute; size selection characteristic according to United Kingdom practice in accordance with the recommendations of the Johannesburg Conference of 1959.

measurements place emphasis on classes of workplace known to be dusty and on those which have consistently not met the dust guidelines of the Mines Accident Prevention Association.

The TLV for the respirable mass of free silica as introduced by the American Conference of Governmental Industrial Hygienists in 1968 is effectively 0.1 mg/m³ under a specified size-selection characteristic.[66] This standard has a mandatory status under federal jurisdiction in US metallic and non-metallic mines.[67] Sweden is currently adopting a dust index based on the size-selection characteristic recommended at the Johannesburg International Conference on Pneumoconiosis in 1959.[68] This index for free silica is unity at a mass level of 0.1 mg/m³.[69] A recent study of the US National Institute for Occupational Health and Safety proposes a TLV of 0.05 mg/m³.[70] This proposed standard is based on epidemiological data for workers in the Vermont granite sheds where the amount of quartz in total dust is 25 to 35 per cent.[71] The original studies were based on the use of the impinger instrument, which counts particles of total dust. Later studies have inferred a mass equivalent of respirable dust for impinger counts of total dust. The NIOSH criteria document states: 'It is recommended that the studies in the granite industry be confirmed and that similar studies be undertaken in other industries to determine more precisely the significance of free silica in those industries so that alternate recommendations can be made, should they be indicated.'[72]

To establish a statutory dust standard it is essential to conduct

epidemiological research that will relate silicosis to the conditions of dust exposure as measured by a standardized instrument at the workplaces where the standard is to apply. It has been previously noted that while free silica is a known hazard, mine and plant aerosols are complex and may contain, in addition to compounds of the metal mined, compounds of many other metals and of the rare earths, along with oil globules, radioactive particles and diesel particulates.[73] It is therefore recommended:

That to provide a basis for establishing a statutory standard or standards for time-weighted average respirable dust exposure in Ontario mines and plants, the Occupational Health and Safety Branch commission epidemiological research on the relation of incidence of silicosis and of other pulmonary effects to the structure and quantity of aerosols respired in Ontario mines.

That where more than one recognized toxic component is present in the aerosols the standard specify how an effective combined exposure limit is to be determined.

The determination of statutory standards in the end involves a decision on what constitutes an acceptable human risk in the face of desired economic benefit, available technology and economic cost. Hatch has carefully reviewed practices in setting standards in the USA as contrasted with those in the USSR.[74] The Threshold Limit Value used by the American Conference of Governmental Industrial Hygienists implies an accepted risk after extended exposure for a small number of susceptible persons.[75] In practice the crucial evidence is that of human response to the levels actually achieved at the workplace. Environmental standards for the workplace that are not complied with are a fiction.

Until the gravimetric method of measurement is in effective operating practice and the appropriate statutory standard or standards are invoked, it is imperative that the current dust-measuring practice based on the konimeter be continued as a means of controlling dust levels. It is therefore recommended:

That the existing code of requirements for dust measurement in the uranium mines as issued by the chief engineer of the Mines Engineering Branch remain in force.

That the system of measurement and reporting being conducted by the Mines Accident Prevention Association continue in operation and be subject to independent monitoring as recommended.

The current broad guidelines of the MAPAO have been developed on the basis of the percentage of free silica in total dust. There appears to be no logical ground for altering the basis of these guidelines to the percentage free silica in respirable dust, which is a highly variable quantity.

The effect of the foregoing recommendations is to retain the present system of dust measurement while gravimetric methods are being introduced and proven. When the statutory standard for time-weighted exposure to dust averaged over a working shift is invoked for all mines, the industry should be free to continue or discontinue current konimeter practice. To terminate this practice before a personal dust standard is effectively in place would remove a useful, if imperfect, control of the work environment in the mines.

WORK ADJUSTMENT AND WORKMEN'S COMPENSATION

The terms of reference of the Commission directed it to review the present basis for workmen's compensation as this relates to environmental health matters affecting miners. Compensation under the Workmen's Compensation Act for silicosis and other industrial diseases is not directed to the impairment as such, but is rather to prevent, in part, loss of wages as a consequence of the person being unable to continue in his regular employment.

The process by which a claim is accepted for silicosis is as follows. Each new claim is examined by the medical staff of the Board, which reviews the occupational history of the claimant and the radiographic and other records, and seeks a recommendation from the Advisory Committee on Occupational Chest Diseases of the Ministry of Health.[76] That committee conducts a clinical assessment of each referred claimant to determine if there is silicosis and observable impairment. When impairment is present, the Advisory Committee recommends to the Board a percentage disability to be assigned for purposes of compensation. The Board then decides whether to accept the claim and the amount of the award. The Commission believes this administrative practice to be just and equitable.

The problem of silicosis in the Elliot Lake uranium mines presents new and pressing problems with regard to compensation policy and practice. The Commission believes that *extended rehabilitative provisions* should be made for persons who have worked in the uranium mines, and that these should be provided to persons who experience exceptional conditions of exposure to other occupational health hazards.

The principle underlying the recommendations is one of *work*

adjustment, that is, of providing, to workers likely to be impaired by continued exposure to environmental health hazards in their current work, assistance in transferring to work involving what may reasonably be imputed to be less exposure. The Workmen's Compensation Board, management, and unions each have an important role to play. The Board can assure that such services are available when initiative by management and supported by unions is insufficient.

In framing the recommendations, the Commission has found it essential to review the central tenets of compensation under the Workmen's Compensation Act, which are rooted in the landmark report of Chief Justice Meredith.[77] The essence of workmen's compensation is that risks of work manifested in accidents and disease attributable to work should be compensated out of the wealth generated by the industry employing the worker. In every case of industrial injury or disease that impairs a worker's ability to do his or her work (or results in death) partial compensation for lost income is made without regard to fault.[78] In accepting this system of compensation the worker and the employer give up the legal right to action for negligence under common law.[79] Rights to damages for pain and suffering and for the inconvenience, discomfort, and anguish associated with being maimed or disfigured are part of the rights under common law given up by the worker in obtaining the advantages of compensation without regard to fault. One provision under Section 42(6) allows for a lump-sum payment in compensation for serious facial disfigurement.[80]

The Workmen's Compensation Board provides payment for loss of income. In addition, it provides medical, hospital, and rehabilitative services, including retraining programmes designed to minimize the effect of injury and disease on the person and on his or her capacity to maintain income.

The funds to compensate mine workers derive from levies made by the Board on employers in Class 5 of Schedule 1 of the Act.[81] These assessments include the costs of administration of the Board and of the Mines Accident Prevention Association. Currently, the costs paid out of these assessments, when averaged over the employers in Class 5, amount to about 6 per cent of the gross annual payroll of the employees covered. The Act now treats industrial disease in the same manner as an accidental injury.[82] That is, a workman recognized as suffering from a compensable industrial disease is eligible for awards under the Act as from the date of recognition, and there is no longer the requirement that the worker remove himself from the industrial exposure deemed to be contributive to the disease.

TABLE 13

Comparative exposure times in years from first dust exposure in Ontario to dust effects in lungs (Radiographic 4)

Type of mine exposed in	Period found 1960–4	1965–9	1970–4
Uranium only	3.2	7.5	11.3
Uranium and other	13.2	15.1	18.7
Other than uranium	15.0	16.6	20.6

NOTE: Dust exposure in Ontario only.
SOURCE: Workmen's Compensation Board, 'Silicosis Report Programme,' November 1975, Table 2.4

Silicosis is a disease that, unlike lung cancer, is clearly attributable to an identifiable cause, namely, silica-laden dust at the workplace. In addition radiography of the lungs yields clear precursor indicators that precede the disease. The disease involves a lessened capacity for work. Thus the sequence of pulmonary events for a person *who has become a silicotic* is a radiographic category 4 (dust effects), followed by a radiographic category 5 (radiological silicosis), followed by the disease silicosis. By no means all mine workers whose lungs come to exhibit dust effects actually progress to become silicotics. Nevertheless, *in a probabilistic sense* dependent on the intensity of continuing exposure to dust, a radiographic 4 may be presumed to be evidence of the likelihood of progression to a state of disease, even though there is at this stage no clinical evidence of lung impairment.

It is but common sense that younger workers especially should be given the opportunity and assistance to get out of current dust exposure if there is strong statistical evidence or a basis for clinical judgment that they are likely to progress to impairment or increased impairment unusually rapidly by continuing in their current work. This is the principle of work adjustment, which the Commission believes should be invoked in exceptional exposure situations such as those in the Elliot Lake Mines. Table 13 provides comparative statistical data on dust exposures required to produce dust effects in the lungs of mine workers.[83] This table shows that miners who have worked only in Ontario and only in uranium mines and who came to exhibit dust effects in their lungs in the period 1970–4, reached that state in approximately half the time of persons who have worked in other than uranium mines. It is therefore recommended:

That the current employees in the Elliot Lake uranium mines who are

silicotics or exhibit dust effects (radiographic 4) in their lungs be eligible for a voluntary programme of work adjustment; that this programme be supported by management and unions; and that the Workmen's Compensation Board provide rehabilitative compensation and supportive counselling services to assist the persons involved.[84]

The Board's entitlement to provide rehabilitative compensation is defined in Section 53, which reads: 'To aid in getting injured employees back to work and to assist in lessening or removing any handicap resulting from their injuries, the Board may take such measures and make such expenditures as it may deem necessary or expedient, and the expense thereof shall be borne, in Schedule 1 cases, out of the accident fund and, in Schedule 2 cases, by the employer individually, and may be collected in the same manner as compensation or expenses of administration ...'

This section refers to injured workmen. While silicotics are clearly injured persons and eligible for rehabilitative compensation designed to sustain income *and* to lessen further impairment, it is not clear that persons with dust effects and no clinically observable impairment are injured in the sense of the above section.[85] It is therefore recommended:

That Section 53 of the Workmen's Compensation Act be amended as necessary to provide clear entitlement for rehabilitative compensation based on the principle of work adjustment for persons subject to exceptional exposure to environmental hazards at work.

Invoking a principle of work adjustment must not be permitted to lessen the commitment of management, labour, and government to reduce the exposure of workers to all known hazardous substances to levels of acceptable risk. If one worker, on grounds of personal protection, is assisted to move from one workplace to another, entailing less intense exposure to a given substance, it is reasonable to infer that another worker will take his or her place. In a direct sense, then, work adjustment leads to the exposures associated with a given level of industrial production being spread over a larger set of persons.[86] In this regard it is recommended:

That any employer who rotates job assignments for workmen with the intent of limiting the occupational exposure of any persons to any hazardous environmental condition be required to obtain the formal approval of the Occupational Health and Safety Branch and to maintain permanent occupational records which clearly define the persons, tasks, locations, hazardous conditions, and time intervals involved.

Workmen's compensation exists to deal as fairly as possible with the fact that accidents and industrial disease do, and inevitably will occur. The principle of work adjustment represents a significant extension of the concept of compensation made with the intent of lessening the likelihood of initial impairment or of further impairment in those special situations of susceptibility and exceptional exposures that can be clearly identified. At the same time, it is the palpable hazards of the workplace that are at issue, and workmen's compensation is not a suitable vehicle for dealing with broad questions of social disability.

A work-adjustment programme for a person should contain assisted opportunity for one or more of the following elements: 1/ transfer to equivalent or new work within the mine or plant of current employment; 2/ transfer to comparable or new work in a mine, plant or other industry at another location in Ontario; 3/ retraining for the new work if required; and 4/ planning and carrying out the relocation of the family and home where that is indicated.

Further, in effecting work adjustment for a person it is essential that his or her current income be sustained. It is therefore recommended:

That during a programme of personal rehabilitation through work adjustment, and for a minimum period of two years thereafter, the income of the worker be maintained in accordance with the provisions of the Workmen's Compensation Act for full compensation which allow the board to pay in non-taxable compensation 75 per cent of the difference between the current rate of pay and the rate of pay applicable at the date of entry into the programme;

That in addition to wage maintenance, the worker in a work-adjustment programme be eligible for rehabilitation training allowances as provided for in the Workmen's Compensation Act;

That, further, the worker be entitled to reasonable costs for medical and personal counselling beyond that provided by the Workmen's Compensation Board, and to reasonable moving, travelling, and related relocation costs when these are applicable.

The Commission's impression is that mine workers by and large are committed to mining. It is therefore essential that there be no hindrance to their mobility for purposes of work adjustment resulting from the administrative practices of the Board in levying charges for disability pensions

against employers. The practice has been to charge the employer of a silicotic, at the time of his recognition, the full disability pension costs for the lifetime of the person, even though the person may have come to this employer with dust effects in his lungs.[87] If the present policy of assessing companies is continued, it is recommended:

That when the lungs of a worker exhibit dust effects and the worker seeks the opportunity through work adjustment to take employment with a new employer, the new employer not be held liable for any disability pension or other costs for silicosis or disease conditions related thereto that may be levied as a consequence of the person becoming a silicotic at a future date.

This problem, under current administrative practice, does not exist for silicotics.

A work adjustment programme offers no panacea for the employee and his family. It involves a decision whether the expected benefits of personal well-being that may or may not accrue from moving out of one form of environmental exposure into another place of work will outweigh the economic, personal, and family costs of uprooting and change. When counselled to do so, younger persons should, in the Commission's view, be encouraged, and if necessary required, to undertake work adjustment. The programme provides no special assistance if the worker elects to remain in his current employment. With regard to work adjustment and so-called pre-silicotic effects, it is essential that all evidence be marshalled that can assist the making of decisions. It is therefore recommended in particular:

That the Occupational Health and Safety Branch commission research on the radiographic records related to miner's certificates to assess the relative rate of progression of persons in and out of dust.

The foregoing analysis has made reference primarily to the current work force at Elliot Lake. The Commission's intention is that it should be applicable as far as is feasible to the Uranium Nominal Roll of all persons who have worked in the uranium mines and to other less obvious subpopulations of exceptional exposure.

Of the some fifteen thousand persons having one or more months of exposure in the uranium mines to the end of 1974, the great majority have, since about 1962, dispersed widely from these mines. There is no feasible way of tracing the majority, but it is reasonable to suppose that many will not now be in dust exposure. However, the Commission recommends:

That persons on the Uranium Nominal Roll who exhibit dust effects (radiographic 4) within twenty years of entry into Ontario dust exposure, and who have been employed in dust exposure in the uranium mines for a cumulative interval of five or more years from 1954 to 1975 inclusive, be eligible for rehabilitation assistance under a programme of work adjustment.

Finally, since the principle of work adjustment is a basic one, it is recommended:

That where there is evidence that the exposure of any person to silica-laden dust has been substantially in excess of established dust guidelines or standards and the person has exhibited dust effects in his or her lungs within twenty years of first exposure to dust in Ontario, the person be eligible for work adjustment rehabilitation assistance.

This recommendation has two purposes. The first is to assist younger persons for whom there may be some benefit. The second is to ensure that management, labour, and government address themselves to exceptional conditions of exposure as well as to average conditions.

Having examined the details of the policy of work adjustment and rehabilitation assistance that the Workmen's Compensation Board has initiated for the current population of workers at Elliot Lake, the Commission believes this policy, as it concerns silicotics and persons with dust effects, effectively addresses the principles that have been stated.

An effective programme of work adjustment calls for the co-operation of management and labour. Managements can facilitate work adjustment within the range of workplaces that characterize their operations. It is here that work adjustment is likely to be most meaningful. They must act generously. The distinctive unity of the industry gives it special opportunity to facilitate an over-all programme of work adjustment. While unions may properly argue that the problem is not of their making, they can improve local work adjustment opportunities by making special provision for such persons not to be subject to conventional seniority rules. The latest collective bargaining agreements at the Elliot Lake Mines make such provision.[88] Both unions and management deserve commendation for these arrangements.

In all of these matters it is imperative that the privacy of the worker be protected and that initial counselling be undertaken privately between the worker, his attending physician, and the staff of the Workmen's Compen-

sation Board. Once the person elects to undertake work adjustment, his special status will of necessity be known by his actual and potential employers.

For reasons elaborated in chapter 3 the Commission's endorsement of a work adjustment policy for silicotics and pre-silicotics in the uranium mines is based on evidence that the risk of silicosis is substantially higher than the risk of attributable lung cancer.

1 Free silica, as distinct from bound silica, in such compounds as silicates
2 The Ontario classification scale for x-rays was adapted from South African practice and has been used in its current form since 1937. It is distinctly different from the current international classification system adopted by the International Labour Organization in 1971 (*ILO International Classification of Radiographs of the Pneumoconioses, 1971*, Occupational Safety and Health Series No. 22, Geneva, 1972). Five on the Ontario scale corresponds approximately to one on the ILO scale.
3 These are associated with old surface milling operations.
4 There have been many reviews of radiological and disease data relating to silicosis in the mining industry. These include two studies by J.F. Paterson commissioned by the government (J.F. Paterson, *Silicosis in Hardrock Miners in Ontario*, Toronto: Department of Mines, Bulletin 155, 1959; and *Silicosis in Hardrock Miners in Ontario: A Further Study*, Toronto: Ministry of Natural Resources, Bulletin 173, 1973), reports and papers of the Ontario Mining Association, reports of the McIntyre Research Foundation and of the Workmen's Compensation Board. The majority of these sources are documented in Dr Paterson's first report and in the briefs to the Commission from the McIntyre Research Foundation and the Mines Accident Prevention Association. The most comprehensive report to date was issued by the Workmen's Compensation Board in March 1976 (W.C. Wheeler, *Statistics on Silicosis Among Miners in Ontario*, Workmen's Compensation Board, March 1976). The historical use of aluminum powder as a prophylactic agent for silicosis is reviewed in Brief 99, and assessments of its use are given in the reports of Paterson and in J.E. Cowle, 'Health hazards of dust inhalation (pneumoconiosis),' *Canadian Mining Journal*, Oct. 1970, 64. Its use is not favoured in Germany or South Africa.
5 An historical review of the development of the Board's policies in compensating silicosis is given in its brief to the Commission (transcript 4702–25). Under the current Workmen's Compensation Act, S. 1(2), ' "silicosis" means a fibrotic condition of the lungs sufficient to produce a lessened capacity for work caused by the inhalation of silica dust.' Under S. 118(10) an employee is entitled to compensation only after dust exposure in Ontario for periods amounting to at least two years.
6 The data used in Figures 2 and 3 derive from the Silicosis Disability Index issued in November 1975 by W.C. Wheeler, chief of Statistical Services of the Workmen's Compensation Board as part of the Medical Statistics Program established by the Board in co-operation with the Mines Accident Prevention Association in 1950.
7 Dominion Bureau of Statistics, *Canadian Life Tables, 1960–1962*, Ottawa: Queen's Printer, Catalogue Number 84-516, 1964
8 Paterson, *Silicosis* [1973], 7–8 and 13–14
9 McIntyre Research Foundation, *Brief to the Royal Commission*, Table MRF6, Appendix A updated through 1974 at the request of the Commission.
10 Since many workers move from job to job within, between, and outside mines, they may move into and out of dust exposure during their careers. Further, some cases of silicosis

are found years after workers have left the mining industry. Hence, elapsed time is always greater than or equal to years of dust exposure.

11 Paterson, *Silicosis* [1973], 33
12 Accurate man-years-at-risk were not available to permit a proper epidemiological calculation. The factors determined are qualitatively correct. The period of averaging of population was chosen in relation to the observed elapsed time from first dust exposure to silicosis.
13 The recognized cases derive from the retired as well as the working population.
14 Tests of other reasonable averaging periods did not lead to any significant change in the pattern of incidence factors by time period.
15 J.E. Cowle, E. Mastromatteo, A.C. Ritchie, 'An unusual pneumoconiosis in the Ontario mining industry,' *Transactions of the 34th Annual Meeting of the American Conference of Governmental Industrial Hygienists*, May 1972, 126–35. It has been suggested that irradiation of the lungs in uranium miners enhances the fibrotic effects of silica dust. See for example E. Trapp et al., 'Cardiopulmonary function in uranium miners,' *American Review of Respiratory Disease*, 101, 1970, 27–43.
16 As of 1 January 1974 all industrial disease recognized under the Workmen's Compensation Act was treated as industrial accidents are and became eligible for receipt of compensation at the date of recognition. This policy change is likely to have a significant effect on the future statistical pattern of recognized silicosis and indeed of other compensable conditions such as hearing loss.
17 The policy of the Workmen's Compensation Board is to charge all costs of compensation for silicosis to the company in whose employment a person is at the time he is recognized, regardless of his occupational history.
18 'An unusual pneumoconiosis.' The first case of silicosis was charged to a uranium mine in 1963. All cases charged to uranium mines to the end of 1974 experienced first dust exposure in Ontario in 1930 or later.
19 The cases considered were all those for which the first disability rating was less than 100 per cent. The average disability rating among the groups was consistent at about 25 per cent.
20 These radiological classifications are different from the classifications by 'mine group charged' as used with reference to Table 8.
21 Sufficient time has not yet elapsed for any later five-year data.
22 Of all the persons who at some time exhibit dust effects in their lungs many of course do not progress to become silicotics.
23 The Workmen's Compensation Board, in co-operation with the Ontario Mining Association, has developed a Nominal Roll of persons who have experienced one month or more of exposure in the uranium mines including those in the Bancroft area. To the end of 1974 this roll had some fifteen thousand names.
24 Ontario Ministry of Health, *Survey of Certain Conditions of The Respiratory Organs Among Persons Employed Underground and in Surface Crushers and Mills of Two Operating Uranium Mines at Elliot Lake, Ontario*, Toronto, April 1975, 49; for silicosis refer to 9–13, 37–41, 45, 48–9
25 To the end of 1974, some 347 radiological ratings of 4 and 140 ratings of 5 had been found among persons on the Nominal Roll. Continuing radiological records for some of the persons on the Nominal Roll are not available because they have moved out of Ontario or out of the industry. The current dust-exposed population at Elliot Lake represents about 7 per cent of the total number of persons on the Nominal Roll.
26 Paterson, *Silicosis* [1959 and 1973]
27 The full relation which I believe this authority should have with mine workers is spelled out in chapter 6.
28 A new mine at Agnew Lake near Espanola opened in the spring of 1976.
29 Ontario, Special Committee on Mining Practices at Elliot Lake, *Report: Part 1. Accidents*

and Related Representations; Part 2. Mining Practices, Toronto: Ontario Department of Mines, Bulletin 155, 1959.
30 Special Committee on Mining Practices at Elliot Lake, Appendix D, 1–2
31 Mining Act, Part IX, S. 169(1), (2), and (6) and S. 213 (1), (10), and (12a), and S. 214 (1) and (4)
32 It has been noted that the provision for this Association is made under the Workmen's Compensation Act, S. 119 (1).
33 For a commentary on the politics of mineral development see H.V. Nelles, *The Politics of Development*, Toronto, 1974, chap. 11.
34 1 micron = 10^{-6} metres.
35 T.F. Hatch, P. Gross, *Pulmonary Deposition and Retention of Inhaled Particles*, New York, 1964
36 Settling velocity may be on the order of centimetres per hour.
37 International Labour Office, *Dust Sampling in Mines*, Geneva: ILO Occupational Safety and Health Series, No. 9, 1972
38 G.H.C. Norman, 'Methods of sampling and dust determination in the mines of Ontario,' *American Institute of Mining and Metallurgical Engineers*, November 1937, 1–20
39 Magnification 150 times in a dark field
40 Mines Accident Prevention Association, *38th Annual Report*, May 1969, 8
41 Mines Accident Prevention Association, *Semi-Annual Dust Survey Procedure*, 1974
42 Exhibit No. 8 – Figures 1–5 of brief submitted by Denison Mines
43 C.S. Gibson, 'Limiting factors in dust control and ventilation,' a paper presented at the Sixth Conference of McIntyre Research Foundation on Silicosis held in Toronto, Ontario 1–3 February 1954 [Gibson was safety director and chief engineer and secretary, Committee on Silicosis, Mines Accident Prevention Association.]
44 Exhibit No. 130 – Memorandum: 'Dust control in uranium mines, 25 May 1955,' included in the Ontario Mining Association's presentation to the Commission
45 Mines Accident Prevention Association of Ontario, *First Report Dust Control, Ventilation and Radioactivity at Bicroft Uranium Mines Limited – Subject: Survey of Underground Operations*, January 1956. Similar surveys by the same Association were reported on: *Faraday Uranium Mines Limited (All Operations)*, January 1956; *Pronto Uranium Mines Limited (All Operations)*, March 1956; *Quirke Mine, Algom Uranium Mines Limited (All Operations)*, June 1956; *Nordic Mine, Algom Uranium Mines Limited (All Operations)*, January 1957.
46 Exhibit No. 130 – Memorandum: 'Dust control in uranium mines, 25 May 1955,' included in the Ontario Mining Association's presentation to the Commission
47 Ibid.
48 Exhibit No. 135 – included in the presentation by the Ministry of Natural Resources to the Commission as Resource Document No. 2 to its brief.
49 Paterson, *Silicosis* [1959]
50 Ontario Mining Association, *Minutes of Annual Meeting*, 15 June 1959
51 Asbestos mines have been surveyed by the Ministry of Health at the request of the Ministry of Natural Resources.
52 Brief presented to the Commission by L. Williams on behalf of United Steelworkers of America, District 6. (transcript 3411)
53 In Figure 9 the graph for uranium mines includes *all* uranium mines. After 1964 the only operating uranium mines were in the Elliot Lake area. The early dust levels in the Bancroft area mines were comparable to those in the Elliot Lake Mines. The historical pattern shown in Figure 9 is not significantly changed by their inclusion from 1958 to 1964. Workplace-averages by class of mine corresponding to the underground mine-average data of Figure 9 are given in Appendix D, Tables D.2 to D.4. These tables also provide the gross ventilation flow rate in cubic feet per minute per ton of ore hoisted per day.
54 Ministry of Natural Resources, Mines Engineering Branch, letter from W. Bawden to

engineers, 6 July 1959. The current practice of the engineers was confirmed in interviews with senior ministry staff and field staff.

55 'Rafter' dust as settled out from the air at the workplace

56 Mines Accident Prevention Association, *Airborne Contaminants, Mining, Milling, Smelting and Refining*, 1st ed., Toronto, 1969

57 Exhibit No. 2 – Mines Accident Prevention Association, *Comments on Results of Surveys of Air Conditions in Ontario Mines for the period ending March 31, 1974*

58 In chapter 6 the relation of the labour unions to the self-regulatory organizations of industry is discussed.

59 Mines Accident Prevention Association, *Comments on Results of Surveys of Air Conditions in Ontario Mines for the period ending March 31, 1974*

60 Under the existing Mining Act there is no legal recognition of codes of practice, but the chief engineer of the Mines Engineering Branch has issued such codes under the powers conveyed by Section 610. The Commission believes this procedure has been a sound one but intends that such codes should have the significance defined in the Health and Safety At Work Act, 1974, United Kingdom, under Sections 15, 16, and 17. Recommendations for revision in the legal framework of the Mining Act are made in chapter 6.

61 This concept is adopted from Part IV of the Coal Mines (Respirable Dust) Regulations 1975. Statutory Instrument No. 1433, 1975, Health and Safety Executive, United Kingdom

62 After a long period of epidemiological and instrument research, the United Kingdom adopted its first statutory standard for dust in coal mines in September 1975.

Recent reports of experience with gravimetric sampling in US coal mines provide insight into some of the difficulties. The problem of measuring coal dust is simpler than that of measuring the mass of free-silica in the dusts of the ores of metals: US National Bureau of Standards, *An Evaluation of the Accuracy of the Coal Mine Dust Sampling Program Administered by the Department of the Interior – a Final Report to the Senate Committee on Labour and Public Welfare*, np, December 1975; US Comptroller General, *Improvements Still Needed in Coal Mine Dust Sampling Program and Penalty Assessments and Collections – Report to the Congress by the Comptroller General of the United States*, Washington: US General Accounting Office, RED–76–56, January 1976.

63 Different types of instruments measure distinctly different characteristics of aerosols, so that their readings can only be compared on the basis of statistical correlation, preferably in standardized dust clouds. Much of the concern attending the release of the document entitled 'Survey of dust-radiation-diesel exhaust in uranium mines and mills at Elliot Lake, Ontario,' by the Occupational Health Protection Branch, Ontario Ministry of Health, in November 1974, was, in the Commission's view, related to attempts to compare non-equivalent measures of dust deriving from the midget impinger, the konimeter, and gravimetric instruments.

64 G. Knight, T.E. Newkirk, G.R. Yourt, 'Full shift assessment of respirable dust exposure,' *Canadian Mining and Metallurgical Bulletin*, April 1974, 61–72;
P. Chmara, H. McLean, 'Gravimetric sampling in metal mines,' paper presented before the Mines Accident Prevention Association, May 1975
The brief submitted to the Commission by the Canada Centre for Mineral and Energy Technology, Federal Ministry of Energy, Mines and Resources, Canada, reviews Canadian and related research on the measurement of dust (transcript 4143–213).

65 American Conference of Governmental Industrial Hygienists, *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with intended changes for 1975*, Cincinnati, 1975 (henceforth cited as TLV)

66 American Conference of Governmental Industrial Hygienists, *Transactions of the Thirtieth Annual Meeting*, May 1968; TLV 33, 35

67 US Mining Enforcement and Safety Administration, *Metal and Non-metal Mine Health*

and Safety Standards and Regulations, Public Law 89–577, Federal Metal and Non-metallic Mine Safety Act, S. 57-5.1

68 E.J. Orenstein, ed., *Proceedings of the Pneumoconiosis Conference*, Johannesburg, 1959, 619–20

69 Communication to the Commission during its visit to Sweden

70 US Department of Health, Education and Welfare, NIOSH, *Criteria for a Recommended Standard ... Occupational Exposure to Crystalline Silica*, Washington: US Department of Health, Education and Welfare Publication No. 75–120, 121. This document provides an extensive review of international practices.

71 Ibid., 75–7

72 Ibid., 77

73 D.S. Robertson, *Thorium and Rare Earths in the Huronian Rocks of Elliot Lake and the surrounding region*, New York, NY: Paper No. A68-3, The Metallurgical Society of AIME, February 1968.

Radioactive particles are discussed in chap. 3 and diesel emissions in chap. 5 of the present report. It has been suggested that irradiation of the lungs of uranium miners enhances the fibrotic effects of silica. See, for example, E. Trapp et al., 'Cardiopulmonary function in uranium mines.'

74 T.F. Hatch, 'Permissible levels of exposure to hazardous agents in industry,' *Journal of Occupational Medicine*, 14, 1972, 134–7. *Methods Used in the U.S.S.R. for Establishing Biologically Safe Levels of Toxic Substances*, Geneva, 1975.

75 TLV, 1

76 Brief presented to the Commission by the Workmen's Compensation Board (transcript, 4702–35)

77 Chief Justice Meredith, *Report of the Royal Commission on Workmen's Compensation*, Ontario: Sessional Papers, 46, 1914

78 Current regulations provide for up to 75 per cent of the lesser of the current rate of earnings or a rate of $15,000 per annum. Such payments are not subject to federal or provincial income tax.

79 With minor exceptions explained in the Act.

80 Mr Justice McGillivary, *Report of the Royal Commission in the Matter of the Workmen's Compensation Act*, Toronto, 1967, 18–20

81 Workmen's Compensation Act, Regulation 834

82 Ibid., Section 118 (1)

83 See also Figures 5 and 6 for comparative evidence of current rates of progression from radiographic 4 to radiographic 5.

84 Such a programme is now being invoked for current employees at the Elliot Lake mines at the initiative of the Board, unions, and managements. Over the years many silicotics have been provided with work-adjustment opportunities by their employers on an ad hoc basis.

85 Nor is it clear that a person is injured in the sense of Section 53 who has accumulated a specified exposure to radiation or to any other hazardous substance.

86 This result is somewhat analogous to using smoke stacks to lower the danger from concentrated effluents by a process of dilution in a larger volume of the atmosphere. Further, if a younger person replaces an older person he may be subject to higher risk of accident than the person replaced.

87 When a mine ceases operation the continuing liability for silicotics is shifted to the mines of the same type remaining in operation.

88 *Collective Agreement Between Local 5762 United Steelworkers of America and Denison Mines Limited, 1976*, Articles 16 and, especially 16.01; *Collective Agreement Between Local 5417 United Steelworkers of America and Rio Algom Limited, 1976*, Articles 14 and 17.01

3

Lung cancer and ionizing radiation in the uranium mines

INTRODUCTION

Lung cancer, unlike silicosis, occurs in the general population, and is occurring with increasing frequency as shown in Table 14. The disease appears in response to such known cancer-inducing agents as cigarette smoke, ionizing radiation in uranium mines, asbestos fibres, and nickel and arsenic compounds,[1] as well as without recognized cause. Cases of lung cancer attributed to ionizing radiation experienced in uranium mines have been found to appear five or more years after the first exposure to radiation.[2]

While the oat-cell type of cancer has been shown to occur more frequently among uranium miners exposed to ionizing radiation than among unexposed populations,[3] all kinds of cancer are usually indistinguishable in form from those observed in persons who have not been so exposed. Consequently there is no definitive pathological basis for inferring that a particular lesion was induced by ionizing radiation. The relationship of lung cancer to the exposure of uranium miners has been established on a statistical basis by observing that it occurs more frequently among these persons than would be expected in a comparable population of persons not exposed to more than the normal ionizing radiation.[4] Even when a statistically significant excess of observed over expected cases is established, a decision to ascribe a specific case to conditions at the workplace still depends on a judgment of how the person's record of exposure compares with the exposure experienced by other workers. At best there may be epidemiology providing a dose-response relation to support the attribution.[5] The work of Archer et al.[6] shows that uranium miners who smoke cigarettes are much more likely to experience lung cancer than

TABLE 14

Male death rate per 100,000 of population from cancer of the trachea, bronchus, and lung

Period	All ages	Under 15	15–24	25–34	34–44	45–54	55–64	65–74	75+
1950–4	19.83	0.03	–	0.37	4.70	31.28	83.74	112.17	91.64
1955–9	25.08	–	0.05	0.59	4.97	36.78	112.03	162.36	128.96
1960–4	30.79	–	0.14	0.54	6.64	39.52	134.98	218.70	181.84
1965–9	37.36	–	0.10	0.66	8.46	42.85	145.94	297.45	252.21
1970–4	45.87	0.02	0.11	0.68	10.23	48.69	167.71	346.89	382.20

NOTE: Deaths categorized according to the *International Classification of Diseases*, A51, 8th Revision
SOURCE: Ministry of Health, Ontario

non-smoking miners. In such a situation there is no single assignable cause for an individual case of cancer.

There is epidemiological evidence that the risk of the development of lung cancer in silicotics is not greater than in the general population. On the other hand it has been suggested that irradiation of the lungs in uranium miners may modify and possibly enhance the fibrotic effect of silica.[7]

IONIZING RADIATION IN THE URANIUM MINES

The ionizing radiation in mines arises from the spontaneous radioactive disintegrations associated with the decay chains of the naturally occurring isotopes of the elements uranium and thorium.[8] There is a stage in each of these chains at which a gas is produced. The hazard of radiation in air breathed into the lungs arises mainly from the emanation into mine air from rock faces, broken rock, and mine water of the radioactive gas radon; thoron and actinon are radioactive gases of relatively lower hazard.

Throughout the rock in the Canadian Shield, uranium is present in about 3 parts per million and thorium in about 9 parts per million. These elements are more concentrated in many mineral deposits, especially in uraniferous ores. Wherever they are present in significant quantities there is a potential hazard from ionizing radiation in mine air if ventilation is not adequate. There is evidence from several countries, including Canada, of hazard from ionizing radiation in mines other than uranium mines.[9] The conditions in non-uranium mines in Ontario will be reviewed.

The uraniferous ores under development in Ontario, as noted in Table 15, have similar uranium grades and are therefore subject to comparable

TABLE 15

Some comparative characteristics of uranium ores (approximate average values)

Location	Lbs/Ton U_3O_8	Lbs/Ton ThO_2	Lbs/Ton Rare earths	Percentage of free silica
Agnew Lake	2.5	4	13	65
Elliot Lake[a]	2.5	1	6	65
Bancroft[b]	2.5	1	<1	5[b]–15

a North geological branch, which includes current operating mines
b Madawaska Mine (formerly Faraday Mine)
SOURCE: D.S. Robertson, 'Thorium and rare earths in the Huronian rocks of Elliot Lake and surrounding region,' *TMS-AIME meeting*, New York Feb., 1968; D.S. Robertson, 'Thorium and uranium variations in Blind River ores,' *Economic Geology*, 57, Dec. 1962, 1175–84

ionizing radiation from the uranium chains which lead to radon and actinon. The Agnew Lake ore has a distinctly high thorium content, the element that sends thoron gas into mine air. The Agnew Lake ores are also rich in rare earths.[10]

Practical control of ionizing radiation in mines has been based on measurements of dust and of radon and its daughters, which derive from the abundant uranium isotope U^{238} and cause most of the radioactivity in mine air.[11] However, since ore of higher than usual thorium content[12] is to be mined at Agnew Lake, the Commission recommends as a matter of precaution:

That the Atomic Energy Control Board confirm the extent to which thoron gas and its daughter products contribute to the irradiation of the respiratory system and other organs of workers in Ontario uranium mines.

THE MEASUREMENT OF IONIZING RADIATION

The analysis which follows will deal for the most part with the effects of radon and its daughter products. Radon gas in mine air is transformed by spontaneous nuclear disintegrations into a sequence of distinctive particles called radon daughters. The chain of disintegrations, which terminates in a stable form of lead, is shown in Table 16. When disintegrations occur in mine air, a fraction of the resultant particles remain free in the form of

TABLE 16

Disintegration series for radon and its daughters

Common name	Isotope	Principal radiation	Alpha energy (MEV)	Beta maximum energy (MEV)	Gamma ray quanta per disintegration	Average gamma ray energy (MEV)	Half-life
Radon	$_{86}Rn^{222}$	*Alpha*	5.486				3.825 d
Radium A	$_{84}Po^{218}$	*Alpha*	5.998				3.05 m
Radium B	$_{82}Pb^{214}$	Beta, Gamma		0.65	0.82	0.295	26.8 m
Radium C	$_{83}Bi^{214}$	Beta, Gamma		3.13 (23%) 1.67 (77%)	1.45	1.050	19.7 m
Radium C¹	$_{84}Po^{214}$	*Alpha*	7.68				2.73×10^{-6} m
Radium D (Radio lead)	$_{82}Pb^{210}$	Beta, Gamma		0.018	1	0.047	22 y
Radium E	$_{83}Bi^{210}$	Beta		1.17			5.02 d
Radium F	$_{84}Po^{210}$	Alpha	5.298				138.3 d
Radium G	$_{82}Pb^{206}$						Stable

NOTE: The half-life is the time taken for half of an initial number of atoms that are not replenished to undergo radioactive disintegration; *y* means years, *d* days, and *m* minutes. Italics highlight major sources of alpha energy which may give rise to lung cancer.

SOURCE: D.A. Holaday et al., *Control of Radon and Daughters in Uranium Mines and Calculations on Biologic Effects*, Washington: US Department of Health, Education, and Welfare, Public Health Service Publication No. 494, 1967, 6

unattached ions, while most particles become adsorbed to water droplets and particles of mineral dust, diesel soot, and so on. The combination of radon gas and these complex particulates forms the aerosol inhaled by miners and deposited in part on the surfaces of the respiratory pathways.

At each characteristic nuclear decay there is released radiation in the form of beta rays, gamma rays, or alpha particles.[13] The damage to living cells, with the complex biological consequences that may lead to cancer, occurs when these particles and rays produce ionization along their paths of impact on the human body. Beta and gamma rays contribute primarily to external whole-body irradiation, alpha particles to internal irradiation.

In the uranium mines, both external and internal irradiation of workers have been measured. For external irradiation a personal dosimeter, in the form of a film badge or semiconductor detector calibrated for gamma and beta rays, has been used over a working shift or series of shifts.[14] The personal dosimeter is read in Rems.[15] There has been no code of requirements for measurement of whole-body irradiation, but mines from time to time have taken spot measurements.

The maximum permissible dose to the whole body of persons designated as Atomic Radiation Workers[16] is stipulated by Schedule II of the Atomic Energy Control Regulations to be five Rems per annum, which is equivalent to 2.5 millirems per hour for a working year of two thousand hours. Table 17 gives representative current measurements in an Elliot Lake Mine. An ore grade of 6 lbs of U_3O_8 per ton in Elliot Lake mines is exceptionally high. This grade leads to a dose rate slightly over one-half the maximum permissible dose. Measurements in United States mines with ores of comparable grade reveal a pattern of values similar to that in Table 17.[17]

Despite the fact that current records show external whole body irradiation from gamma and beta rays to be within the existing standard as specified by Atomic Energy Control Regulations, for two reasons the Commission believes that some sampling by personal dosimeter using solid-state detector technology should be carried out. The industry is expanding, and ore grades vary. It is essential that there be assurance that whole-body dose is kept as low as practicable. Further, such measurements have value in providing a data base for epidemiological research on the long-term effects of whole-body irradiation at these levels.[18] Therefore it will be recommended that the Atomic Energy Control Board issue a code of guidance for the measurement of external irradiation and the maintenance of related occupational records.

It is the alpha particles associated with nuclear decay of radon, Radium A

TABLE 17

Gamma radiation by film badge in an Elliot Lake mine

Personnel task	Ore grade in lbs of U_3O_8 per ton	Number of badges	Average total millirem	Work exposure hours	Millirem/ hour	Equivalent Rems/year
Shift boss	–	6	16	64	0.25	0.5
Miners	2.8	5	42	72	0.60	1.2
	6.0	3	103	72	1.40	2.8

NOTE: Maximum permissible dose is five Rems/year under Schedule II, Atomic Energy Control Regulations
SOURCE: Rio Algom Mines Ltd, 1975

and Radium C′ in the aerosol breathed by miners, that are considered to contribute the major internal irradiation of the bronchial and bronchiolar epithelium of the lungs.[19] Of this internal dose to the lungs, by far the greater proportion is delivered by the daughters of radon.[20]

In Ontario uranium mines the internal irradiation of workers' lungs by radon and its daughters has been measured indirectly in terms of the level of radioactivity present in the mine air. The current measure is the Working Level (WL) and the Working Level Month (WLM).[21]

Measurements of radon-daughter radioactivity have been taken by industry at representative workplaces since the issuance by the Mines Engineering Branch of a code of requirements in March 1957.[22] Exploratory measurements had been made in 1955–6 under circumstances described in chapter 2. Historical mine average values of radiation intensity expressed in Working Level Months per annum have been compiled by the Mines Engineering Branch and are given in Table 18. Table 19 shows the corresponding cumulative Working Level Months that a person would experience were he to have worked continuously in one mine under mine average exposure conditions. The development of a radiation standard for the uranium mines will be examined in detail later in this chapter. For the present it is noted that prior to 1968 there was no required limit to radiation stated in the code of requirement for measurements. From 1955 to the end of 1967 the guideline accepted by the Mines Accident Prevention Association and the Mines Engineering Branch appears to have been 12 WLM per annum or its equivalent.[23] At the end of 1967 the code on radiation exposure was revised to include a limit of 12 WLM per annum.[24] In 1972 a further revision reduced the limit of exposure from 12 to 8 WLM per annum for 1973

TABLE 18

Radiation exposure factors for Ontario uranium mines
(Working Level Months per year)

Year Standard (Guideline)	1955 (12)	1956 (12)	1957 (12)	1958 (12)	1959 (12)	1960 (12)	1961 (12)	1962 (12)	1963 (12)	1964 (12)	1965 (12)
Bancroft Camp											
Canadian Dyno			96.0	44.4	12.0						
Bicroft	51.6	40.8	19.2	12.0	12.0	9.6	6.0	8.4	4.8		
Faraday	84.0	84.0	72.0	52.8	43.2	24.0	16.8	15.6	6.0	4.8	
Elliot Lake Camp											
Pronto		20.4	20.4	20.4	16.8	22.8					
Rio Algom–Quirke No. 1		15.6	15.6	15.6	9.6	8.4					
Rio Algom–New Quirke											
Rio Algom–Nordic		15.6	15.6	15.6	15.6	9.6	7.2	6.0	3.6	4.8	6.0
Can-Met			18.0	6.0	7.2	7.2					
Denison			8.4	15.6	18.0	25.2	38.4	37.2	32.4	34.8	20.4
Stanleigh Uranium			6.0	3.6	6.0	9.6					
Milliken Lake				8.4	8.4	10.8	7.2	7.2	7.2	7.2	37.2[a]
Stanrock			30.0	30.0	31.2	32.4	34.8	33.6	22.8	24.0	25.2
Northspan-Panel			14.4	9.6	13.2	10.8	13.2				
Northspan–Lake Nordic (Lacnor)			12.0	9.6	12.0	10.8					
Northspan–Spanish America				4.8	3.6						
Northspan-Buckles			12.0	14.4							

NOTE: Weighted average = 0.80 × average for headings, raises, and stopes + 0.2 × average in travelways. This table does not include certain mines, such as Rare Earths Ltd and Greyhawk Mines, for which records could not be found.

Until 1967 the government and industry used a guideline of 1 working level. A standard was first established in the amended Code of Requirements for the Survey of Dust, Ventilation, and Radioactivity at Uranium Mines in Ontario, December 1967.

a Leaching – respirators worn

SOURCE: Ministry of Natural Resources, Mines Engineering Branch

TABLE 18 (concluded)

Year	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Standard (Guideline)	(12)	12	12	12	12	12	12	8	6	4
Bancroft Camp										
Canadian Dyno										
Bicroft										
Faraday										
Elliot Lake Camp										
Pronto										
Rio Algom–Quirke No. 1		2.4	4.8	3.6	3.6	6.0	7.2			
Rio Algom–New Quirke			2.4	2.4	2.4	1.2	2.4	2.4	2.4	1.8
Rio Algom–Nordic	4.8	6.0	7.2	4.8	3.6					
Can-Met										
Denison	14.4	14.4	13.2	8.4	8.4	7.2	4.8	4.8	4.8	4.4
Stanleigh Uranium										
Milliken Lake										
Stanrock	27.6	24.0	18.0							
Northspan-Panel										
Northspan–Lake Nordic (Lacnor)										
Northspan–Spanish America										
Northspan-Buckles										

TABLE 19

Potential cumulative total exposure to radiation in Ontario uranium mines (Working Level Months)

Year	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Bancroft Camp											
Canadian Dyno			96.0	140.4	152.4						
Bicroft	51.6	92.4	111.6	123.6	135.6	145.2	151.2	159.6	164.4		
Faraday	84.0	168.0	240.0	292.8	336.0	360.0	376.8	392.4	398.4	403.2	
Elliot Lake Camp											
Pronto		20.4	40.8	61.2	78.0	100.8					
Rio Algom–Quirke No. 1		15.6	31.2	46.8	56.4	64.8					
Rio Algom–New Quirke											
Rio Algom–Nordic		15.6	31.2	46.8	62.4	72.0	79.2	85.2	88.8	93.6	99.6
Can-Met			18.0	24.0	31.2	38.4					
Denison			8.4	24.0	42.0	67.2	105.6	142.8	175.2	210.0	230.4
Stanleigh Uranium			6.0	9.6	15.6	25.2					
Milliken Lake				8.4	16.8	27.6	34.8	42.0	49.2	56.4	93.6
Stanrock			30.0	60.0	91.2	123.6	158.4	192.0	214.8	238.8	264.0
Northspan-Panel			14.4	24.0	37.2	48.0	57.6				
Northspan–Lake Nordic (Lacnor)			12.0	21.6	33.6	44.4					
Northspan–Spanish America				4.8	8.4						
Northspan-Buckles			12.0	26.4							

SOURCE: Compiled from data provided by the Ministry of Natural Resources, Mines Engineering Branch

TABLE 19 (concluded)

Year	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Bancroft Camp										
Canadian Dyno										
Bicroft										
Faraday										
Elliot Lake Camp										
Pronto										
Rio Algom–Quirke No. 1		67.2	72.0	75.6	79.2	85.2	92.4			
Rio Algom–New Quirke			2.4	4.8	7.2	8.4	10.8	13.2	15.6	17.4
Rio Algom–Nordic	104.4	110.4	117.6	122.4	126.0					
Can-Met										
Denison	244.8	259.2	272.4	280.8	289.2	296.4	301.2	306.0	310.8	315.2
Stanleigh Uranium										
Milliken Lake										
Stanrock	291.6	315.6	333.6							
Northspan-Panel										
Northspan–Lake Nordic (Lacnor)										
Northspan–Spanish American										
Northspan-Buckles										

and from 8 to 6 WLM per annum for 1974.[25] A final revision of the code in 1974 reduced the allowed limit of exposure to 4 WLM per annum for 1975.[26]

The extent to which this sequence of guideline values and stipulated limits was complied with may be judged from Table 18, where the guideline value or code limit is entered for each year at the top of the table. Regular measurements of radiation were not conducted in all mines and hence were not available for audit by the mines inspectorate until 1958. In Tables 18 and 19 there are notable differences in radiation levels and cumulative radiation exposure among the mines. The radiation levels in the mines of the Bancroft area were initially substantially higher than those in Elliot Lake. Although silicosis has not been a problem in relation to the Bancroft mines, the same cannot be said of lung cancer.

RADIATION AND THE RESPONSIBILITY-SYSTEM

Recognition of the problem of lung cancer

From the beginning of the development of the uranium mines, the Mines Engineering Branch of the then Department of Mines, the Ontario Mining Association, and the Mines Accident Prevention Association were aware that they posed unusual potential hazards to health because of the highly siliceous ores at Elliot Lake and because of radiation at both Bancroft and Elliot Lake. The Ontario Mining Association established an internal Advisory Committee on Uranium Mines in 1956 which met regularly until 1964, examined United States and South African practice, and, through the work of the Mines Accident Prevention Association, was made aware of the environmental conditions existing in the uranium mines. The Ministry of Health and Atomic Energy of Canada Ltd provided competent advice whenever it was requested and assisted in particular with problems of radiation measurement. The code of requirements for the measurement of radiation and dust beginning in 1957 is evidence that the need for radiation records was recognized. Until 1968 these measurements were in representative mine locations and not related to individuals. However, the revised code for the mines issued in December 1967 called for the maintenance by the mines after that date of personal radiation exposure records.[27]

In Ontario the recognition by the responsibility-system of a suspected problem of lung cancer among uranium miners gradually came about, notably through deliberations of the Advisory Committee on Occupational Health of the Ontario Mining Association, whose forerunner was the Committee on Silicosis of that organization. In this committee, persons from the staff of the Ontario Mining Association, the Mines Accident

Prevention Association, the industry, the Mines Engineering Branch, the Ministry of Health, and the Workmen's Compensation Board met, at the invitation of the Mining Association, to share understanding of problems of health and safety in the mining industry.[28] A major concern in this committee from the early sixties was the setting up of occupational records suitable for 'making an assessment of the present and future lung cancer risk in uranium miners.'[29] The development of records proceeded slowly. But gradually, through the co-operation of the mines, the Department of Mines, the Ontario Mining Association, the Workmen's Compensation Board, and the Ministry of Health, a Nominal Roll of Uranium Miners was developed by the Medical Statistics Unit of the Board.[30] While this Roll was being developed, the persons on the Committee from the Ministry of Health and the Board conducted exploratory searches for deaths and causes of death of uranium miners in Ontario records of vital statistics.

As the Nominal Roll was improved and updated, estimates of mortality by cause of death were made in the Ministry of Health,[31] and a written report based on incomplete data for deaths in the period 1955–70 was prepared for the Advisory Committee.[32] This report was updated in 1974 to include deaths for the period 1971–2.[33] In essence, this report estimated that, from a total of forty-one lung cancer deaths observed in Ontario in a population of about eight-thousand miners in the years 1955–72, there was an excess of twenty-eight over the thirteen lung cancer deaths to have been expected by reference to all contemporary deaths of Ontario males. The substance of this report was presented at an international conference in September 1974.[34]

At Commission hearings in Elliot Lake, union leaders alleged that the workers whose lives have been and are at risk have not been kept informed about the developing situation in Ontario. The following words convey the intensity of feeling: 'We have been led to believe through the years that the working environment in these mines was safe for us to work in. We have been deceived.'[35]

The Commission has examined in depth the events briefly described above. During this period Mines Inspectors issued many letters of instruction to the mines to improve conditions, and, as Table 18 shows, levels of radiation were reduced. But neither the workers nor their representatives were advised about the emerging status of the problem of lung cancer. The consequence was, and is, that men and their families have been living in fear of the circumstances of their work. The Commission sees no excuse for not telling working people the truth, however difficult and imperfect that may be. Nor is it tolerable that there should be no forum in which

representatives of workers can engage other parties in the responsibility-system in frank deliberation over the risks to health involved in work.[36]

The central public responsibility for initiative in ensuring that the problems of the work environment in the uranium mines were dealt with expeditiously and thoroughly then rested with the Department of Mines and now rests with the Ministry of Natural Resources. In the period 1972 to 1974, the allowed radiation exposure limit was lowered from 12 WLM per annum to 4 WLM per annum. But the delineation of the underlying problem has been slow and remains incomplete. Indeed at times it has not been clear whether initiative was considered to rest with industry or the responsible ministry. Staff in the Ministry of Health and the Workmen's Compensation Board have worked, and continue to work, with inadequate resources to assist in illuminating problems outside their jurisdiction. In this sense there is compelling need for new clarity in roles within the responsibility-system, especially when there is growing awareness of an evident threat to the lives of workers. The Commission therefore recommends:

That the Occupational Health and Safety Authority be given by statute the authority and responsibility to conduct a full and expeditious review of any emergent situation in which the health and safety of workers in mines are believed to be at unexpected risk.

If adequate occupational health records are maintained and subjected to regular review there will be less of the crisis atmosphere that currently pervades problems of occupational health. Ad hoc reviews are less than satisfactory, but in the absence of resources for, and a planned commitment to, occupational health they are necessary.

MORTALITY EXPERIENCE OF URANIUM MINERS IN ONTARIO

In the circumstances of the uranium mines the Commission has been called upon 'to identify relevant data related to lung cancer.' The following assessment is based on a study conducted with the full co-operation of the Workmen's Compensation Board, the Ministry of Health, and the Ministry of Natural Resources. The limited statistical study conducted by the Commission had two purposes: 1/ to seek verification of the extent of the excess of lung cancer predicted in the earlier studies; 2/ to determine if, within the circumstances of the Ontario Uranium Nominal Roll, there is statistical evidence of a risk of cancer dependent on radiation exposure at the levels experienced.

TABLE 20

Distribution of deaths by province of residence

Residence at time of death	Deaths from all causes	Lung cancer deaths (included in all causes)
Maritimes	24	4
Quebec	100	9
Ontario	692	63
Prairies	56	5
British Columbia	75	3
Outside Canada	2	1
Total	956	81

SOURCE: Commission Project: 'Mortality experience of uranium miners in Ontario'

The study has been based on the Ontario Uranium Nominal Roll as of 31 December 1974 prepared by the Workmen's Compensation Board.[37] This Roll contains data on 15,094 persons who worked one or more months in dust exposure at the uranium mines in the period 1955 to 1974 inclusive. The very great majority of these persons at some time had worked underground in both dust and radiation exposure. A few had exposure limited to dust on the surface. In June 1975, the Commission arranged with Statistics Canada to conduct, in co-operation with the Registrars-General of the provinces, a search of all national vital statistical records for deaths of persons on the Nominal Roll. In parallel with this work the Statistical Services Unit of the Workmen's Compensation Board, at the request of the Commission, began manual extraction of data from its files based on Miners Certificates to permit estimation of the man-years at risk and to provide radiation histories for a random sample of persons on the Nominal Roll.[38] The radiation history of each lung cancer death was also determined.

The death search yielded 956 acceptable matches to the Nominal Roll, of which 81 were certified as caused by cancer of the lung.[39] The distribution of the deaths by province of residence is shown in Table 20.

The expected numbers of deaths to be compared with the actual deaths were determined from vital statistics for the male population of Ontario as a whole.[40] To determine whether or not actual deaths from lung cancer are in significant excess of those expected, the comparison in Table 21 was prepared. As of the end of 1974, lung cancer deaths were in significant

TABLE 21

Comparison of actual and expected deaths by calendar period

	Deaths from all causes			Lung Cancer deaths (included in all causes)		
Period	Actual	Expected	Excess (+) or deficiency (−)	Actual	Expected	Excess (+) or deficiency (−)
1955–9	57	59.43	−2.43	1	1.21	−0.21
1960–4	223	177.14	45.86	12	5.54	6.46
1965–9	280	261.77	18.23	18	12.49	5.51
1970–4	396	396.20	−0.20	50	25.84	24.16
Total	956	894.54	61.46	81	45.08	35.92

NOTE: A deficiency means that fewer persons on the Nominal Roll died than would be expected on the basis of Ontario male mortality experience
SOURCE: Commission Project: 'Mortality experience of uranium miners in Ontario'

excess by a total of 36 cases, or 80 per cent of the expected deaths.[41] The excess first becomes apparent for the period 1960–4.

New employees in the uranium mines are added to the Nominal Roll each year, and it is reduced in number only through death. Hence the accumulating expected number and actual number of deaths will increase as years pass, particularly because the major population growth in the Roll, as suggested in Figure 8, occurred about 1960. This population is now aging and faces rising death rates from natural causes. It is not possible on the basis of the Commission's study to predict how Table 21 will evolve as time elapses.[42] It is imperative that the mortality experience of the uranium mines be followed up. The Commission therefore recommends:

That the Occupational Health and Safety Branch commission a review of the mortality experience of persons on the Ontario Uranium Nominal Roll on a biennial basis for at least ten years.

To place the current excess cancer deaths in proper perspective it is necessary to examine the actual and expected deaths under major causes as presented in Table 22. Several distinctive features of the mortality experience of uranium miners in Ontario now emerge. The over-all net excess of 62 deaths derives from a gross excess of 188 deaths from violent causes and a major deficiency of 126 deaths from natural causes within which lung cancer is in excess. The large excess of deaths from violent causes derives mainly from those other than motor vehicle accidents and suicides. The

TABLE 22

Actual, expected and excess deaths by major causes

All causes 956 : 894.54 : 61.46	Violent causes 400 : 212.38 : 187.62	Motor vehicle accidents 93 : 77.48 : 15.52
		Suicide 47 : 48.50 : (−1.50)
		Remainder 260 : 86.40 : 173.60
	'Natural' causes 556 : 682.16 : (−126.16)	Cancer of lung 81 : 45.08 : 35.92
		Cancer of stomach 11 : 12.70 : (−1.70)
		Tuberculosis 0 : 2.47 : (−2.47)
		Miscellaneous respiratory (including silicosis) 28 : 32.20 : (−4.2)
		Arteriosclerotic heart disease 195 : 287.69 : (−92.69)
		Hypertension, etc. 6 : 6.03 : (−0.03)
		Remainder 223 : 293.99 : (−70.99)

NOTE: An excess is positive, a deficiency negative. The numbers in each sequence are actual : expected : excess (deficiency) deaths.
SOURCE: Commission Project: 'Mortality Experience of Uranium Miners in Ontario'

remaining deaths from violent causes arise largely from accidents in the mines or in other industrial employment. In chapter 4 a detailed analysis of deaths of this type will be given. Here it should be noted that the related excess of 173 violent industrial deaths is almost five times the excess due to lung cancer.

In the class of causes designated as natural there is no significant excess or deficiency for cancer of the stomach, tuberculosis, hypertension, and miscellaneous respiratory diseases, which include silicosis. The excess for lung cancer is the more striking when it is noted that there is a major deficiency of 93 for arteriosclerotic heart disease and a deficiency of 71 for all other causes.[43] The latter deficiencies may be attributable to the natural physical selection entailed in the recruitment of persons to an occupation requiring strenuous work. However, all of the population has not remained in mining.

The impact of the foregoing pattern of excess deaths on the lives of uranium miners can be further illustrated with Table 23.[44] In terms of the

TABLE 23

Actual deaths (ascertained and estimated), expected deaths and excess deaths for all causes by age group

Age at death	Actual deaths: Ascertained	Actual deaths: Estimated	Expected deaths	Excess (+) or deficiency (−) based on estimated actual deaths (%)
15–39	328	376	229.06	+64
40–49	285	293	275.18	+ 6
50–59	240	268	261.56	+ 2
60+	103	135	128.73	+ 5
Total	956	1,072	894.53	+19.8

NOTE: For estimated actual deaths, see n. 39
SOURCE: Commission Project: 'Mortality experience of uranium miners in Ontario'

total excess of deaths resulting from all causes, it is the youngest age group that suffers by far the most conspicuous excess, and deaths primarily through industrial accidents are the largest contributor. A study of loss of potential life years based on Canadian male life tables for 1960–2 has shown that each 'extra' fatal accident in the population of the Nominal Roll took nearly thirty-five years of future lifetime, compared to an average of twenty-two years for each 'extra' death from lung cancer. In aggregate the deprivation of life years by excessive fatal accidents was *eight times* that resulting from the excess of lung cancer deaths. This fact has important implications for policy on work adjustment discussed below.

EXPOSURE TO IONIZING RADIATION AND THE RISK OF CANCER – ONTARIO EVIDENCE

An excess in the occurrence of lung cancer in an occupational group does not in itself establish the identity of a causative agent in the working environment. However, since the link between lung cancer and exposure to ionizing radiation has been well established in other populations,[45] the Commission has sought evidence that there is such a link in the particular circumstances experienced by the population on the Ontario Nominal Roll.

With respect to uranium miners, the major epidemiological studies in the USA[46] have involved populations that have experienced average radiation exposures higher by a factor of ten or more than the persons on the Ontario Uranium Nominal Roll, and efforts to relate US experience to lower levels of exposure are based on extrapolation. The Commission has been able to

TABLE 24

Comparative characteristics of cancer cases having the highest and lowest radiation exposures experienced in Ontario

Case characteristic	Highest exposure group (average of 20 cases)	Lowest exposure group (average of 20 cases)
Radiation exposure	195 WLM S	5.8 WLM S
Years of exposure	7.2 years	0.6 years
Exposure per annum	33 WLM S	16 WLM S
Elapsed time, entry to death	13.8 years	11.8 years
Age at entry	37.7 years	41.5 years
Year of entry	1956	1958

discover no epidemiological data on excess lung cancer among uranium miners, based on radiation records of the completeness of those available in Ontario, at the radiation levels encountered here, in a population as large as that on the Uranium Nominal Roll. The Ontario body of data is believed to be of major significance for the delineation of the risks of lung cancer among uranium miners and the full exploitation of these data is essential. Except in the search for deaths, the Commission has conducted analysis based on samples of these data.

Table C. 4 contains available case characteristics for the lung cancer deaths identified by the Commission.[47] The cases are listed in sequence by cumulated exposure to radiation. The highest radiation exposure received in the uranium mines of Ontario prior to death from lung cancer was 375 WLM and the lowest zero; the mean value was 75 WLM. Table 24 compares some characteristics of the quarter of the cases with highest exposure with those of the quarter with lowest exposure.

To determine if there is statistical evidence that the risk of lung cancer among the persons on the Uranium Nominal Roll is dependent on the cumulative radiation exposure experienced in Ontario uranium mines, the series of eighty-one cancer deaths was related to a comparison series of eighty-one survivors drawn from a set of names randomly selected from the Nominal Roll.[48] The comparison series is taken to be representative of all those persons who entered the mines in the period 1955–74 and survived to the end of 1974.

Several statistical tests were conducted using the recorded ages, exposures to radiation, and places of occupation for the cancer deaths and the randomly selected comparison series. These tests are described in appen-

dix C. The hypotheses included: 1/ that the risk of lung cancer is unrelated to radiation exposure incurred in Ontario mines; 2/ that the risk of lung cancer is unrelated to the region of employment (Bancroft or Elliot Lake); 3/ that the risk of lung cancer is independent of the period of entry into uranium mining.

Hypothesis 1 was tested using several configurations of the data, and in each case was rejected.[49] The Commission concludes that under the conditions of exposure to radiation in Ontario uranium mines in the period 1955–1974, there is statistical evidence that the persons on the Uranium Nominal Roll have experienced a risk of lung cancer that is related to radiation exposure received in Ontario. The tests, based on sample analysis, indicate that risk increases with exposure and that a linear dependence on cumulative WLM is consistent with the sample data. Therefore, on the basis of the data on excess mortality from lung cancer and the sample evidence on risk as related to cumulative WLM, the Commission will recommend that the standard for exposure to ionizing radiation be reviewed.

Because the Bancroft area mines have been shut down, there has been a strong tendency in the hearings of the Commission to relate lung cancer primarily to the Elliot Lake Mines. For this reason hypothesis 2 was tested. There is statistical evidence based on samples that for persons who ever worked in the Bancroft area mines the risk of lung cancer has been 2.2 times that for persons who never worked at Bancroft (see Table C. 2). Further, there is very proper concern about the continuing risk of lung cancer relative to those that pertained in the early period of the mines. A test of hypothesis 3 was conducted for the period before 1958 as against the period thereafter. There is statistical evidence that the risk of lung cancer for a person who entered the mines before 1958 was 2.5 times that for a person who entered after that date (see Table C. 3). The outcome of the latter two tests of location and time of entry are consistent in character with the radiation data in Tables 18 and 19.

THE EVOLUTION OF THE CURRENT STANDARD FOR RADIATION EXPOSURE

Since the labour unions have properly expressed deep concern over conditions in the mines it is essential to examine how the current radiation exposure limit of 4 WLM per annum for internal irradiation was arrived at, and to consider by whom it should be reviewed. The Commission con-

cludes that the review should be effected by the Atomic Energy Control Board, whose historical role is now examined.

THE PROBLEM OF JURISDICTION

When the uranium mines opened, they were contractors to Eldorado Mining and Refining Ltd, a federal crown company. The Atomic Energy Control Board issued operating licences to the mines under which provincial regulations for safety and health were invoked subject to any regulations made under the Atomic Energy Control Act.[50] Substantive regulations relating to health and safety were first issued in 1960, and apply to persons defined as atomic radiation workers.[51] At the time of writing the Atomic Energy Control Board had not formally declared uranium miners to be such workers. Hence the governing standards with respect to the exposure of uranium miners to ionizing radiation have been those invoked by the Atomic Energy Control Board under provincial regulations. Provincial regulations have been set by the Department of Mines (now Ministry of Natural Resources) with advice from the Ministry of Health, the industry, and special consultants.

Although the Atomic Energy Control Board from time to time exercised a review role by meeting with provincial authorities and mine managements, it did not do so on a regular basis and received no regular reports from provincial authorities. It became especially concerned about conditions in the uranium mines following the release in 1967 of a major US report on lung cancer among uranium miners.[52]

The intervention of federal authority in the uranium mines through the Atomic Energy Control Act and the concomitant intervening jurisdiction of the Canadian Labour Code[53] has not rested easily with either the industry or the provincial authorities. Indeed the validity of the federal jurisdiction has been tested in the courts.[54] In the matter of legal liability for workmen's compensation the Commission has been advised that miners are not 'employees' under the Government Employee's Compensation Act[55] and are not therefore eligible to make claims against the federal government, even though an injury might be imputed to want of adequate inspection.

The historical record of conditions in the uranium mines clearly reveals that the current arrangement of undelegated federal jurisdiction and invoked provincial regulation is unsatisfactory. Workers in uranium mines should no longer suffer for want of the commitment of resources by all parties and the effective concertation of authority and talent. The Commis-

sion believes it to be essential for the public good that the Atomic Energy Control Board fully exercise its fundamental regulatory responsibility over the whole of the nuclear fuel cycle from the mining of ore to the operation of reactors.

To clarify jurisdictional responsibilities in these matters, it is therefore recommended:

That the Atomic Enegry Control Board review the basis for and issue explicit regulations establishing the maximum permissible annual exposure to ionizing radiation for workers in uranium and thorium mines and mills;

That the regulations for maximum permissible exposure delineate how all significant components of external and internal irradiation are to be accounted for and indicate how total exposure and related dose is to be evaluated;

That the regulations for maximum permissible exposure and related dose be interpreted in units that can be monitored by practical means in uranium and thorium mines and mills.

Further, as a matter of fundamental principle the Board as a public regulatory agency should in issuing its regulations make publicly available a summary of the grounds on which it bases its judgment.

To fulfil its responsibility of interpreting radiation standards for the mining and milling of uranium and thorium ores, the Atomic Energy Control Board should take certain initiatives in research. In particular it is of the highest importance that a reliable personal dosimeter for alpha radiation be developed for use in the mines and that a reliable 'instant' working level meter be developed to facilitate engineering monitoring of mine environments. Prototype technology is already available. The Commission therefore recommends:

That the Atomic Energy Control Board
1/ have research conducted relevant to current circumstances a/ *on means for measuring all components of ionizing radiation effective in contributing significantly to the irradiation of the lungs, other organs, and tissues of workers in Ontario uranium and thorium mines and mills; and* b/ *on the spatial and temporal distribution of ionizing radiation and related particulates in these mines and mills;*

2/ issue codes of guidance a/ *for the frequency and location of sampling required to determine both the radiation exposure of individual workers in Ontario mines and mills and the general state of the mine and mill environment;* b/ *for the selection, use, maintenance, and calibration of instruments for measuring ionizing radiation both for the determination of individual exposures and for the monitoring of the general mine and mill environment;* c/ *for the identification of persons for whom records of radiation exposure should be kept; and* d/ *for the form, preservation, and use of occupational records for exposure to all significant components of ionizing radiation; and*
3/ facilitate, with the assistance of the federal Department of Health and Welfare, epidemiological research on a national basis.

If the Board exercises the foregoing initiative clearly and in open consultation with industry, labour, and provincial authority there should be benefit to all concerned. The public and the workers should expect nothing less than the full co-operation of all parties. The Board's position in these matters has been positively stated in its brief to the Commission.[56] In this regard it may be noted that exceptional efforts are made to monitor and to control the radiation exposure of workers at the high-technology end of the nuclear fuel cycle at nuclear reactors. More extensive attention should be given to those who work in mines where the day-to-day exposures to ionizing radiation may be orders of magnitude larger than those received by workers around reactors.

To clarify provincial responsibility, the Commission recommends:

That the Province of Ontario, through the Occupational Health and Saftey Authority, establish by statute a standard for maximum permissible annual exposure to ionizing radiation for workers in uranium and thorium mines and mills, and that this standard be in conformity with the regulatory standards of the Atomic Energy Control Board;

That the Occupational Health and Safety Branch be assigned by provincial statute the responsibility to direct:
1/ the establishment and review of occupational health records for workers in uranium and thorium mines and mills, for regulatory and epidemiological purposes;
2/ the preparation of a code of practice for the sampling and measurement of ionizing radiation in a manner suited to the determination of the exposures of individual workers in uranium and thorium mines and mills and

that this code of practice be in conformity with the code of guidance issued by the Atomic Energy Control Board.

The Commission believes that mines should be required to comply with standards of individual exposure to ionizing radiation *and* with complementary engineering standards indicative of over-all environmental control of radiation. It therefore recommends:

That the Mines Inspection Branch prepare regulations defining the kinds and frequencies of measurements of ventilation and radiation necessary to enable it to audit the engineering operational characteristics of uranium and thorium mines and mills;

That these regulations be in conformity with the related code of guidance established by the Atomic Energy Control Board;

That the Occupational Health and Safety Authority specify
1/ a level of radiation in mine or mill air measured at any time in any occupied workplace which, if exceeded, requires that corrective action be taken immediately; and
2/ a level of radiation in mine or mill air measured at any time in any occupied workplace which, if exceeded, requires closure of the related workplace until the level of radiation is reduced below that specified in 1.

The purpose of the last recommendation is to ensure that radiation in the working environment is kept as low as possible through procedures of engineering monitoring. This form of control is complemented by the requirement that personal exposures to radiation not exceed the statutory limit.

THE ORIGIN OF THE CURRENT ONTARIO STANDARD FOR RADIATION EXPOSURE

Let us now review the basis for the current limit of exposure to radiation of 4 WLM, which relates to the internal irradiation of the lung by alpha particles. The standard for radiation exposure in Ontario uranium mines has been influenced by two major sources – the recommendations of the International Commission on Radiological Protection and US practices and legislation.[57] When mines began production in 1955 the International Commission on Radiological Protection had issued a new recommendation

that the maximum permissible concentration of radon and its daughters in air be 100 picocuries per litre. This level was accepted as the basis for the early Ontario guideline when the 1957 code of requirement for radiation measurement was implemented during 1958.[58] This guideline was for practical purposes equivalent to the Working Level recommended for adoption in US mines by the US Public Health Service in the same period (see n. 11). Thus a radiation guideline equivalent to internationally recommended levels was accepted in Ontario from 1958. However, since the guideline had no statutory significance the question of legal compliance was not initially at issue. Table 18 and the empidemiological evidence provide verification that the worst radiation conditions in most, but not all, mines existed in the period 1955 to 1958, before auditing of conditions by the Mines Engineering Branch was taking place with assistance from the Ministry of Health.

In 1959 the International Commission on Radiological Protection issued a revised recommendation of 30 picocuries/litre as a maximum permissible concentration of radon for a forty-hour week.[59] This recommendation was interpreted in Ontario as a reduction by a factor of three in the maximum permissible concentration and led in 1960 to a major review of the situation by the Departments of Mines and Health assisted by outstanding Canadian and US specialists.[60] There was an informal consensus that it was desirable to shift to the lower guideline over a period of five years.[61]

In the meantime, radioactivity in the air in US mines continued at levels substantially above those in Canadian mines, and a variety of US authorities confirmed the then prevailing 12 WLM per annum guideline.[62] In Ontario the guideline continued at the equivalent of 12 WLM per annum until the end of 1967, when the code of requirement stating this level was issued by the Mines Engineering Branch.[63]

At this time definitive evidence of an excess risk of lung cancer among US uranium miners began to appear (see nn. 1, 52), and internal Ontario evidence of a similar risk was beginning to emerge (see nn. 30, 32). The Ontario code of requirement for exposure to radiation was reduced to 8 WLM per annum effective 1 January 1973 and to 6 WLM per annum effective 1 January 1974. As of 1 January 1973 smoking underground in uranium mines was forbidden. The current level of 4 WLM per annum was made effective as of 1 January 1975 (See nn. 24–6).

From this brief review it will be apparent that the setting of guidelines for exposure to radiation in Ontario mines began in accord with the best available national and international understanding of the problem. The initial intent to follow the revised recommendations of the International

Commission on Radiation Protection (1959) over a period of five years appears to have been set aside in favour of US practices. However, in the USA the limit of 4 WLM per annum was adopted under federal legislation in 1971, albeit with variances allowed.[64]

The Commission has recommended that the Atomic Energy Control Board review the basis for the current standard and confirm a maximum permissible annual exposure to ionizing radiation for uranium miners. In the hearings before the Commission the current level of 4 WLM months has been stated to incorporate a factor of safety of five, to be safe, and to be high by a factor of ten.[65] Each of these judgments has been based on different data or interpretations. The following notes outline some of what the Commission considers to be relevant data at this time.

THE BASIS FOR A STANDARD

A recent extensive review of the history of the development of radiation standards has stated that 'there is now no longer any real question of recommending a level of exposure to ionizing radiation that in the light of present knowledge can be considered absolutely safe. The "safety" of an exposure in particular circumstances must be determined by the risk deemed acceptable in that circumstance. This philosophy of exposure requires as a pre-requisite an assessment of risk associated with the circumstance.'[66] This review is in accord with the positions of the International Commission on Radiological Protection[67] and of the Ministry of Health.[68] Further, a recent major review of lung cancer among uranium miners in the USA states:

> the possible potentiation of radiation effects by cigarette smoking, diesel fumes and other agents in mine atmospheres is not really pertinent to the setting of permissible levels for radon daughters at this time. As such agents are identified, attempts should be made to reduce the risk from their presence; but until that risk is substantially reduced, the permissible level for radon daughters should be based on evidence collected in the environment in which miners continue to live.[69]

The mortality study of the Commission indicates that in the circumstances experienced by persons on the Uranium Nominal Roll in the years 1955–74 there has been a significant excess risk of lung cancer. The sample analysis undertaken indicates that the excess risk is related to exposure to radiation. The number of excess cases of lung cancer, conservatively estimated to be thirty-six for the period 1955–74, is based on a comparison with the experience of the Ontario male population as a whole. For purposes of public health the Commission regards this as the appropriate

reference population, but for epidemiological understanding of differential risks in uranium and other types of mines a study using matched populations of non-uranium miners and non-miners is important. It is therefore recommended:

That the Occupational Health and Safety Branch commission a study of the mortality experience of the Ontario Uranium Nominal Roll relative to appropriately matched sample populations of non-uranium miners and non-miners in Ontario.

THE NATURE OF THE DATA AVAILABLE FOR SETTING A RADIATION EXPOSURE STANDARD

There is no direct way of measuring *in situ* within the respiratory pathways the energy in Rads of ionizing irradiation delivered to the bronchi and lungs by radioactive particles in the aerosol breathed by uranium miners. The Working Level is a measure of the radioactivity of radon daughters in mine air before it is breathed. The Working Level Month is a measure of average exposure over a period of one month. As the number of WLMs per annum increases it is inferred that the human dose of ionizing irradiation increases in proportion. Other measures of radioactivity in mine air, such as of radon gas alone, are used and may be preferable as indirect indicators of dose.[70]

Whatever measure of radioactivity in mine air is used, there is a fundamental problem in relating it to the actual dose of ionizing irradiation in the lungs and to the biological consequences. Using mathematical models of the human lung extensive research has been conducted on the relation between the WLM unit of exposure and the energy dose of irradiation in Rads.[71] The estimates of dose derived by these methods vary by at least a factor of ten.[72] Further, in the absence of definitive knowledge of how the incident energy of irradiation is distributed over the surface of the respiratory pathways and lungs, there is no general agreement on the number of Rems of biologically effective irradiation corresponding to the energy of alpha irradiation in Rads.[73] It is not surprising therefore to find a variety of interpretations of the biological significance of exposure to a particular mine environment (see nn. 1 and 57). Thus a representative of the Atomic Energy Control Board stated before the Commission that exposures of 4 WLM per annum and 12 WLM per annum could both be consistent with the maximum permissible biological dose of 15 Rems per annum to the lungs as allowed by the regulations under the Atomic Energy Control Act for atomic radiation workers.[74]

For these reasons, direct epidemiological evidence in the circumstances

of exposure of the particular working population is considered to provide the best basis upon which to review the standard for exposure to radiation. The epidemiological evidence accessible to the Commission on the existence of lung cancer among miners may be divided into two parts – one in which the average exposure to radiation has been very much higher than in Ontario uranium mines, and another in which the estimated exposures have been comparable to those in Ontario uranium mines. The first group involves experience in the United States.[75] The most recent major study indicates that there is an excess risk of lung cancer at exposures down to and including the range 120–359 WLM.[76] This report concludes in part that 'these evaluations have failed to find any plausible alternative to the hypothesis that radon daughter exposure is causally related to the excess lung cancer risk in the 120–359 WLM category'[77] and that 'other epidemiological studies of situations where human lungs were irradiated were not only consistent with the observations of lung cancer in uranium miners, but indicate that excess lung cancer occurs at lower radiation levels than could be adequately studied among [US] uranium miners.'[78] The statistical data derived by the Commission on the basis of analysis of samples are consistent with the foregoing conclusions. But the Commission's statistics are inconsistent with certain analyses of US data that suggest that a definite exposure-dependent increase in cancer risk will not occur unless some 600 WLMs of exposure have been accumulated.[79]

Let us now consider evidence on exposures estimated to be comparable to those in Ontario. In Swedish underground iron mines in the period 1950 to 1970 a significant excess of lung cancer has been experienced in the presence of radioactivity due to radon and its daughters at exposures estimated to have been in the neighbourhood of 120 WLM with an annual exposure rate of about 4 WLM.[80] It has been reported that in South African gold/uranium mines exposures at the level of about 4 WLM per annum give rise to no significant excess of lung cancer (see n. 9, Basson et al.). In both the South African and Swedish studies the exposures of miners were roughly estimated because no regular radiation measurements were taken during the years of exposure.[81] For French uranium mines, where radiation exposure records extend back to 1958 and average exposure has been about 4 WLM per annum, it has been stated that there is as yet insufficient basis for a clear epidemiological analysis.[82]

From the foregoing evidence for Sweden, South Africa, and France, no clear understanding emerges. At the reported levels of exposure, the data necessary for a clear statistical delineation of the relative risks are careful radiation measurements, a large number of person years at risk, and a

significant number of cancer cases. It is here that the Ontario records of extensive radiation measurements over a period of twenty years, and a Nominal Roll of over fifteen thousand persons at risk constitute, in the Commission's view, epidemiological evidence of singular importance.

With respect to Ontario records it is important to note that cumulative exposures until 1968 have been determined from mine average radioactivity based on measured levels in headings, raises, and stopes, adjusted for the travel time of workers to and from their workplace through the travelways. The use of mine averages for individuals may lead to overestimation or underestimation of exposure by a factor of perhaps two. For statistical purposes there is nothing superior to the mine average data, which is based on large numbers of measurements. No corrections have been made for vacations or variations in work week, which in the early developmental period undoubtedly involved varying amounts of overtime.

There is a question whether persons on the Nominal Roll have experienced significant exposure to radiation prior to or possibly after working in the Ontario uranium mines.[83] For the cancer deaths, the available occupational records of the Workmen's Compensation Board were checked and five of the eighty-one cancer deaths were confirmed as having had some employment in uranium mines outside Ontario in a mixture of occupations prior to working in Ontario. These cases, identified in Table C-4, are scattered through the eighty-one cases. Since radon is now known to have been present in many non-uranium mines, it is important to have some estimate of average cumulative exposure to radioactivity that may have occurred among the population on the Ontario Nominal Roll before uranium mining began in Ontario.

The Mines Accident Prevention Association conducted a radiation survey of non-uranium mines in 1961, and further measurements were made in the period 1970–5.[84] The average reading in the 1961 survey of gold mines, where a significant fraction of the readings were taken in dead ends, was 0.07 WL or 0.8 WLM per annum. In the 1970–5 surveys, the readings were still lower, and with rare exceptions no measurable levels were found in the nickel mines. Levels of radon and associated daughters are strongly influenced by the level of ventilation in mines. A plausible estimate of average pre-uranium mining exposure for a person who worked in other Ontario mines prior to entering the uranium mines in 1954 may be taken as 1 WLM per annum. A study of the occupational histories of the eighty-one cancer cases indicates that these persons had an average of eleven years of work in mines other than Ontario uranium mines and that eight of these years were in other Ontario mines. Not all of these exposures occurred

before the persons worked in the uranium mines. No occupational records are readily available to determine if there has been exposure in uranium mines outside Ontario among persons who left the Ontario uranium mines.

The unions have raised the question of the accuracy of the company records of radiation measurements because no spot-checking of these was undertaken by the Mines Engineering Branch. In the early period, isolated instances of improper or inconsistent operation of instruments occurred. The Ministry of Health provided calibration services for instruments until 1969, when, at the suggestion of the Atomic Energy Control Board, the Elliot Lake Laboratory of the Canada Centre for Mineral and Energy Technology began to provide this service to the industry. In March 1974, tests, including the calibration of instruments, were conducted by the Environmental Health Directorate of the federal Department of Health and Welfare at the request of the Ontario Ministry of Natural Resources.[85] The measurements by the mines provided a slight overestimation of the radiation levels measured by the Directorate. A further extensive series of independent measurements including radon daughters were made in the uranium mines in the period May to October 1974 by the Ministry of Health.[86] The measurements made by the mines were found to be consistent with those taken by the Ministry.

The Commission believes that the Ontario records, which are based on a very extensive set of measurements, are generally valid and that the estimated cumulative exposures of persons based on Ontario uranium mining experience are acceptable for statistical purposes.

THE CANCER RISK SITUATION

The Commission has estimated that to the end of 1974 the excess lung cancer deaths in the population of the Nominal Roll are approximately equal in number to the expected cancer deaths, forty-five in rounded numbers. This is surely an unacceptable risk from occupational exposure.

The means available to limit the risk both for those remaining in and entering the uranium mines are twofold: first, to lower the annual increment of exposure to ionizing radiation for the whole population; second, to lower or eliminate exposure to known conjoint factors such as cigarette smoking.[87] A third and more questionable means of limiting risk, one based on work adjustment, will be discussed later.

In regard to lowering radiation exposure the Commission has recommended that the Atomic Energy Control Board review the standard of maximum permissible annual exposure to ionizing radiation for uranium

miners. Since the Commission's study of data based on the Ontario Uranium Nominal Roll provides no evidence supporting the hypothesis of a threshold of exposure below which there is not significant excess risk, the concept of a maximum safe exposure is not tenable on the basis of these data. Further, for the range of exposures experienced in Ontario the Commission has found no evidence based on data of comparable scope that clearly confirms the existence of a threshold. Therefore, until contrary evidence is presented, the Commission considers the issue to be that of setting the standard at as low a level as is practically and economically feasible, having regard to the human risks that are acceptable in return for the benefits of nuclear power.[88] If there is no level of exposure to ionizing radiation significantly higher than background exposure that can in the light of present knowledge be considered absolutely safe, then the judgment of an acceptable level of risk in uranium mining should, in the Commission's view, be based on the combined risks of respiratory disease and disabling accidents.

The Commission has identified the levels of risk as expressed in current experience. Since everyone accepts voluntary and involuntary risks daily, and since susceptibility to disease in the human population varies, finite risks, including those of accidents, lung cancer, and silicosis in uranium mines must be accepted. It has been noted that the number of potential life years lost from fatal accidents of mainly industrial origin among the population on the Ontario Uranium Nominal Roll outnumber those lost from lung cancer by a factor of about eight times. It is desirable that the total risks be reduced. But the operative level of risk of industrial disease and injury is not settled simply by setting environmental standards. It is determined by individual, legislative, and social judgments as expressed in work practices and their supervision, in regulatory standards and processes of enforcement, and in practices of compensation. All these matters are pertinent and should not be considered in isolation. One reality is that current gross risks for uranium miners greatly exceed those for workers at nuclear reactors.

With respect to risk of cancer mortality attributable to ionizing radiation, current US evidence is that the risk among persons having exposures to alpha radiation at the level of 120–359 WLM is not influenced by the annual rate of exposure.[89] If that is the case in Ontario, the total exposure to radiation over the historical period of exposure is the dominant factor in the excess risk of lung cancer.

For future revisions in the exposure standard it is important to determine, if possible, how a current period of exposure contributes to the risk of lung cancer in the future. Such knowledge may confirm whether or not

the effects of exposure are simply additive or have some reduced or enhanced equivalent value as time passes in association with underlying effects of aging.[90] To that end the Commission recommends:

That the Occupational Health and Safety Authority of the province, in collaboration with the Atomic Energy Control Board, have conducted further epidemiological research based on the exposure to ionizing radiation among Ontario uranium miners;

That the epidemiological research include a study of 1/ the amount and type of exposure effective in raising cancer mortality, 2/ the pathology of lung cancer in miners, and 3/ the effects of cigarette smoking and of other conjoint occupational factors.

It is recommended that this research employ extended sampling methods such as those used by the Commission.

The Commission has already recommended that the extent of the excess cancer mortality be reviewed on a biennial basis for at least ten years; this review will provide a calibration of the ongoing circumstances for the population on the Nominal Roll.

With respect to means of reducing conjoint factors contributing to risk of respiratory cancer the Commission now fervently recommends:

That persons who work in exposure to ionizing radiation in uranium mines cease smoking both at home and at work for their own sakes and in consideration of their families.

The risks of lung cancer related to smoking are voluntary risks, while those related to radiation exposure are largely involuntary. The conjoint risks are real and inescapable for miners who smoke. The industry is of course free to declare that no person who smokes will be eligible for employment in the uranium mines. It may choose to do so, but the Commission believes that such a rule should not be legislated.

The lessening of risks need not and must not wait upon the confirmation of new standards for environmental conditions and such related factors as training and work practices. The dollar costs of improvements are properly passed on to those who benefit from nuclear power. Thus, the evidence of the Commission that an excess risk of lung cancer in the period 1955 to 1974 is related to total Ontario exposures indicates that there must be sustained and meticulous concern to reduce levels of dust and radiation to the lowest

practicable levels. In this regard current conditions in the mines are of the utmost importance both for those who are now entering and for those who already have experienced substantial exposure.

CURRENT CONDITIONS IN THE MINES AND THEIR IMPROVEMENT

Two uranium mines are currently in full operation: Denison Mines Ltd and Rio Algom Mines Ltd. The details of current exposure conditions in these mines will be reviewed. A new mine at Agnew Lake is coming into operation and at least one Bancroft area mine, Madawaska Mines Ltd (the old Faraday Mine), is being reopened. The developmental lessons of the past should be sufficient to alert management, labour, and government to the realization that full and effective compliance with dust and radiation standards must be achieved in developing new mines and reopening old ones. The technical means are available for meeting current standards at reasonable costs. Operations that do not comply should be closed.

The distribution of annual exposures to radiation among persons possessing a Miner's Certificate for the years 1974 and 1975 in the two producing mines is shown in Table 25. The mines are now expanding production, and the population of workers is growing. The average annual exposure in the Denison population decreased from 1.7 WLM in 1974 to 1.2 WLM in 1975 when a major new ventilation raise, the Roman Island raise, first came into use. The corresponding average figures for Rio Algom workers were 1.2 and 1.0 WLM.

In Table 26 the numbers of persons receiving annually in excess of 1, 2, and 3 WLM identify the part of the total population that would be at excess annual exposure if the allowable maximum annual exposure were set at any one of these values. In the two mines together in 1975, some 204, or 11 per cent, of the workers received more than 3 WLM, with an average of 3.7 WLM. The majority of these persons are undoubtedly involved in underground development.

The means to reduce exposure to alpha radiation underground include: 1/ sealing off, where possible, emanations of radon gas; 2/ provision and efficient use of high volumes of ventilation air; 3/ rigorous adherence to sound work practices; 4/ the use in special circumstances of personal protective equipment; and 5/ the application of a policy of job rotation and/or job replacement (work adjustment).

The disintegration of radioactive elements cannot be prevented, so that the generation of radon gas and subsequent alpha emissions cannot be

TABLE 25

Radiation exposure for employees of Denison and Rio Algom Mines 1974–5 (Working Level Months)

Working Level Months	Denison 1974				Denison 1975			
	Workers		Exposure		Workers		Exposure	
	N	%	Average	Median	N	%	Average	Median
0–0.99	342	45.4	0.30	0.20	602	59.8	0.31	0.23
1–1.99	131	17.4	1.42	1.37	150	14.9	1.39	1.32/1.33
2–2.99	85	11.3	2.57	2.64	81	8.1	2.52	2.54
3–3.99	128	17.0	3.51	3.51	132	13.1	3.54	3.52/3.54
4–4.99	62	8.2	4.41	4.35/4.36	37	3.7	4.29	4.32
5–5.99	5	0.7	5.37	5.42	3	0.3	5.48	5.29
6–6.99					1	0.1	6.44	6.44
Total	753	100	1.67	1.20	1,006	100	1.24	0.66

SOURCE: Company data provided by the Ministry of Natural Resources, Mines Engineering Branch

NOTE: Records for Denison Mines Ltd include only hourly-rated underground personnel; records for Rio Algom Mines Ltd include all personnel going underground, as well as staff and hourly-rated and underground mechanics and electricians.

TABLE 25 (concluded)

Working Level Months	Rio Algom 1974				Rio Algom 1975			
	Workers		Exposure		Workers		Exposure	
	N	%	Average	Median	N	%	Average	Median
0–0.99	313	45.2	0.38	0.30	503	57.49	0.36	0.21
1–1.99	260	37.5	1.53	1.54	242	26.66	1.46	1.50
2–2.99	98	14.1	2.33	2.28	99	11.31	2.30	2.23
3–3.99	20	2.9	3.22	3.18/3.20	31	3.54	3.35	3.29
4–4.99	2	0.3	4.65	4.55/4.76				
5–5.99								
6–6.99								
Total	693	100	1.17	1.14	875	100	0.99	0.76

TABLE 26

Cumulative distribution of radiation exposure for employees of Denison and Rio Algom Mines 1974-5

Working Level Months	Denison 1974				Denison 1975			
	Workers		Cumulative exposure		Workers		Cumulative exposure	
	N	%	Average	Median	N	%	Average	Median
≧0	753	100	1.67	1.20	1006	100	1.24	0.66
⋝1.0	411	54.58	2.81	2.98	404	40.16	2.63	2.69
⋝2.0	280	37.18	3.45	3.42/3.43	254	25.25	3.36	3.40/3.41
⋝3.0	195	25.90	3.84	3.78	173	17.20	3.75	3.66
⋝4.0	67	8.90	4.48	4.41	41	4.08	4.43	4.33
⋝5.0	5	0.66	5.37	5.42	4	0.40	5.72	5.29/6.96
>6.0					1	0.10	6.44	6.44
Total	753	100	1.67	1.20	1006	100	1.24	0.66

NOTE: See note to Table 25.
SOURCE: Company data provided by Ministry of Natural Resources, Mines Engineering Branch

TABLE 26 (concluded)

Working Level Months	Rio Algom 1974				Rio Algom 1975			
	Workers		Cumulative exposure		Workers		Cumulative exposure	
	N	%	Average	Median	N	%	Average	Median
$\geqq 0$	695	100	1.17	1.14	875	100	0.99	0.76
$\gtrsim 1.0$	382	54.96	1.82	1.79	372	42.51	1.84	1.69
$\gtrsim 2.0$	122	17.55	2.44	2.31/2.33	130	14.86	2.55	2.37/2.39
$\gtrsim 3.0$	24	3.45	3.07	3.24/3.27	31	3.54	3.35	3.29
$\gtrsim 4.0$	2	0.29	4.65	4.55/4.75				
$\gtrsim 5.0$								
> 6.0								
Total	695	100	1.17	1.14	875	100	0.99	0.76

suppressed. Whereas dust arises only from mining operations, radon gas continuously emanates from seepage water and rock faces and disintegrates into radon daughter products. The emanating surfaces include worked-out areas of a mine and travelways driven in ore. Emanation of radon into the work area from currently broken ore at the workplace is unavoidable and must be swept out by main and auxiliary ventilation systems that are meticulously maintained. Emanation into occupied areas from worked-out areas can be prevented by carefully sealing off such regions with barriers and maintaining them under a negative exhaust pressure through good ventilation design. Experimental technology for coating rock surface with a sealant to retard radon emanation exists,[91] and serious exploration of its use in selected passages should be undertaken in Ontario mines.

Fundamental to the reduction of radiation levels is the effectiveness with which the masses of air pumped into the mine by the main ventilation system are directed in a fresh state to the zones in which persons work.[92] The effectiveness of a regional ventilation system in a mine can be seriously decreased by failure to maintain fans, baffles, and damper doors in optimum configurations. Such failure may arise from carelessness, from inadvertent blast damage, and from equipment failure. One uranium mine has planned a central monitoring system to ensure that the state of the main ventilating network can be continuously monitored.[93] Believing this to be an essential step as the network of mine passages becomes more complex, the Commission therefore recommends:

That each uranium mine install a central monitoring system for its ventilation network to monitor air flow and air quality as indicated by dust, radiation, and other contaminants;

That the Mines Inspection Branch audit the engineering records of performance of mine ventilation systems.

In chapter 2 a statutory requirement was recommended for Codes and Schemes of Practice concerning the control of dust and other environmental contaminants. The Commission intends that these should apply fully to radiation and should be the means for governing accepted standards of work practices in whose implementation the worker fully participates. Substandard work practices that increase present dust and radiation levels cannot be tolerated in the name of production or bonus pay at the expense of the worker's health some years in the future. The shift boss and the men

should be clearly instructed on this matter through established Schemes of Practice. The basic operative responsibility rests with the shift boss, who must be given full support by higher levels of supervision.

Some subsidiary methods are available for protecting persons in special circumstances while at the workplace. Substantial progress is being made in the design of compact visored helmets which flush the face with air obtained from the work environment and filtered by means of a small fan driven by a cap-lamp battery.[94] Such powered devices may prove acceptable for limiting exposure in special tasks. Ordinary respirators are not acceptable devices except for sharply limited periods in exceptional conditions of exposure.[95]

WORK ADJUSTMENT AND JOB ROTATION

The control of radiation exposure by withdrawing a person from his regular workplace deserves special discussion.

Lung cancer is a much more complex disease than silicosis. Silicosis is not expected to occur in the general population, has an identified cause of occupational origin, and often gives precursor radiographic evidence which may forewarn of the onset of the disease, thus permitting the process to be slowed or stopped at a stage that involves very limited disability. These circumstances combine to make a work adjustment programme as recommended in chapter 2 feasible. Lung cancer, however, occurs in the absence of recognized carcinogens and in response to several known carcinogens of which ionizing radiation is one. By the time a lesion is detectable by radiographic methods the likelihood of survival is not great. Recent research on sputum cytological methods has shown that in many persons who have developed bronchial carcinoma there is a distinctive series of five stages of cellular change exhibited in sputum which precede invasive carcinoma.[96] A person who exhibits sputum identified with a given cellular stage does not invariably progress to lung cancer. The Commission is advised that the methodology itself is not at present suited to mass screening in the manner in which radiographic methods have been used.[97] It has recently been used by the Ministry of Health in experimental surveillance of a group of uranium miners at high risk at Elliot Lake who entered these mines before 1962.[98] Until potentially predictive medical tests such as sputum cytology are more fully developed, any policy of work adjustment, as distinct from removal for medical treatment following selective medical surveillance, should be based primarily on records of radiation exposure.

There are clearly two possible types of work adjustment: one based on job rotation and designed to limit annual exposure, the other based on job replacement and designed to limit career exposure.

In the absence of evidence of a threshold below which it may be presumed that there is no risk, it is prudent to assume that the risk of excess cancer of the lung increases with ionizing radiation from zero exposure. Linearity of response to cumulative exposure is accepted by the International Commission on Radiological Protection as a conservative relation for estimating risks. Linearity is consistent with the estimated risk derived by sample analysis in Figure C.1 for the population on the Ontario Uranium Roll. In Figure C.1 the estimated risk at any cumulative exposure is plotted in terms of the estimated proportion of Ontario uranium miners (born before 1933) who had died of lung cancer by the end of 1974. Under these circumstances, the statistical excess of lung cancer derives from the whole range of exposures. In any one specified range of cumulative exposure, the number of excess lung cancers is proportional to the risk and to the number of persons having experienced exposure in that range. Hence, on the premise of linear response to ionizing radiation, it is wrong to attribute the excess of lung cancers to the cases in Table C-1 possessing simply the highest exposures to radiation. In statistical terms, and these are the only terms in which excess lung cancer can be identified, excess cases may arise from cumulative exposure at 0–50 WLM, 50–100 WLM, 100–150 WLM, and so on. And because the risk, although increasing with exposure, is a small number, substantial numbers of persons in all exposure ranges will survive without experiencing carcinoma of the lungs. A particular miner may or may not experience lung cancer at any level of exposure. Medical science is not currently able to determine which individual regardless of exposure to ionizing radiation is destined to develop carcinoma of the lung.

The Commission therefore concludes that there is no ground, based on the health of the population of uranium miners, to justify a policy of work adjustment through removal of a miner from exposure and his placement in another job after he has experienced some designated total exposure to ionizing radiation. If the mines are in a stable state of production, or expanding, the removal of one man will imply his replacement by another, who begins to experience exposure to radiation and to incur risk of lung cancer that may not be expressed until a period of latency elapses. Meanwhile the man he has replaced may die of lung cancer in any event. Hence, the statistical expectation of excess lung cancer can be definitely reduced only by reducing the collective exposure of the working population by

lowering the general level of exposure to radiation, decreasing the number of persons experiencing given levels of exposure, or by decreasing exposure to conjoint factors such as cigarette smoke. Further, when persons change jobs there may be augmented risks of accidents related to age and to training. Younger persons replacing older persons may be at significantly higher risk of loss of life years through disabling accidents. Table 23 provides convincing evidence of differential risks that are age-dependent. The study of accidents and injuries in chapter 4 will elaborate on these risks. Non-smokers replacing smokers would partially compensate for these subsidiary risks. Hence, work adjustment through job replacement to limit career exposures is not an acceptable substitute for the reduction of levels of radiation and of associated factors such as cigarette smoke. The Commission therefore does not recommend a policy of work adjustment through job replacement for uranium miners based on exposure to ionizing radiation. Nor can it endorse the provisions in recent collective bargaining agreements at Elliot Lake for the exercise of special seniority among persons who have experienced specific levels of exposure. If the risk of cancer mortality increases with exposure, such policies cannot in the Commission's view be justified on the basis of serving the health of the population of uranium miners. Indeed the converse effect may occur. The Commission has considered no other grounds. It interprets the decision of the Workmen's Compensation Board to introduce such a policy for workers in Elliot Lake to have been based on the existence of a threshold of exposure at or about 120 WLM below which no significant excess risk of cancer mortality is presumed to exist.[99] The data analysed by the Commission does not support that basis.

Finally, the Commission recommends:

That job rotation within mines conducted to meet the standard for maximum permissible annual exposure to ionizing radiation be permitted only in exceptional circumstances with the explicit approval on a case-by-case basis of the Occupational Health and Safety Branch and with the knowledge of the representatives of the workers.

To the Commission's knowledge, the uranium mines have not engaged in this practice on any significant scale. While work adjustment in relation to ionizing radiation cannot be commended, medical surveillance is of special importance.

MEDICAL SURVEILLANCE IN RELATION TO DUST AND IONIZING RADIATION

Medical surveillance of miners in relation to known health hazards has the following major purposes when coupled to environmental monitoring:
– to provide epidemiological data required to permit standards of exposure to be reviewed and revised;
– to provide epidemiological data required to permit the definition of the effects of conjoint factors in occupational risks (such as cigarette smoking and diesel fumes);
– to provide, through early detection of health impairment,[100] individual evidence that may be used to assist a person through treatment or work adjustment;
– to guide the making and administration of new policy on workmen's compensation, on work adjustment, and on medical surveillance itself.

The cornerstone of medical surveillance for persons who work in dust exposure in Ontario mines has been the medical examinations required for the issuance of a Miner's Certificate.[101] An initial certificate is issued on the basis that 'if the medical officer finds upon examination that the applicant is free from disease of the respiratory organs and otherwise fit for employment in a dust exposure occupation, he shall issue to the applicant an initial certificate.'[102] The holder of an initial certificate is required to present himself for re-examination after eleven months in dust exposure. If the person is then free from disease of the respiratory organs his certificate is endorsed. Finally, if after a further period of eleven months in dust exposure the person is free from tuberculosis of the respiratory organs he is issued a Miner's Certificate, which retains its validity if at an annual examination the holder is found to be free of tuberculosis of the respiratory organs.[103]

The medical examinations referred to have been conducted at Chest Examining Stations set up in the mining districts by the Workmen's Compensation Board. They are now administered and staffed by the Ministry of Health. The radiographic and related occupational records collected through these stations have been filed centrally by the Workmen's Compensation Board, which has gradually developed a Mining Master File of which the Ontario Uranium Nominal Roll is now a part. This massive file contains the core of case data used by the Commission. Unfortunately, important related occupational data, such as the exposure of each miner to ionizing radiation as kept since 1968 by the mines, have not been keyed to the records of the Board. The Commission therefore recommends:

That records of personal exposure to ionizing radiation maintained by the mines be keyed to Miner's Certificate numbers in sequence and to social insurance numbers in sequence and arranged in a format that facilitates linking to the Mining Master File.

There is no subject more important to the protection of workers than the adoption of simple means of keying company and governmental records so that they can readily be linked for manual or computer data analysis.[104]

The system of annual radiographic examinations for renewal of Miner's Certificates was introduced in a period when tuberculosis and silicotuberculosis were a scourge among miners. These conditions no longer exist, and it is no longer necessary to collect radiographic data on every dust-exposed miner every year. Such evidence has been of primary use in administering workmen's compensation for silicosis. A less frequent record of a miner's lung condition can be made equally effective by backdating any compensation award to the date of the immediately preceding examination. When silicosis is effectively suppressed it may be time to abandon the Miner's Certificate as an instrument of regulatory control, but such a step is still considered premature. Therefore, the Commission recommends:

That the frequency of regular radiographic examination of dust-exposed mine workers be reduced to once every two years unless a radiographic change was apparent at the last examination.

The staff at the examining centres should be encouraged to participate in epidemiological studies conducted by or through the Occupational Health and Safety Branch for the purposes of reviewing standards and for the detailed study of health conditions among selected samples of mine workers such as presilicotics and persons at high risk from ionizing radiation. Such sample studies are desirable in developing policies of compensation and work adjustment. They are all too rarely used. Such examining stations should be equipped to perform lung function tests, audiometry, and other tests as determined by the Occupational Health and Safety Branch.

It is understood that the examining physicians currently advise the attending physician of each worker in writing about any respiratory abnormalities that deserve attention either for treatment or for possible compensation. The question of specialized surveillance of persons with exceptional exposure to ionizing radiation deserves particular comment.

It has been noted that sputum cytology is not at present suited to massive

application in occupational medicine. However, sampling methods are feasible. It is therefore recommended:

That tests using sputum cytology be conducted every two years on all persons who have worked in radiation exposure at the uranium mines for five or more years.

Further aspects of medical surveillance will be discussed in Chapters 5 and 6.

LUNG CANCER AND WORKMEN'S COMPENSATION

The Commission has confirmed that an excess of lung cancer, conservatively ascertained to be thirty-six cases, has occurred in the population of 15,094 persons on the Ontario Uranium Nominal Roll for the period 1955 through 1974. On the basis of the estimated under-ascertainment associated with the procedures of the death search as previously described (see appendix C), it is believed that the number of excess cancer cases to the end of 1974 may be about forty-five, which is the same as the expected number of cases of lung cancer. Further, sample analysis has shown statistical evidence that the risk of lung cancer among the population on the Ontario Uranium Nominal Roll in the period 1955 through 1974 is related to exposure to ionizing radiation received in Ontario. If there are additional factors specific to the uranium mines contributing to an excess of lung cancer, they are as yet unknown. It is imperative that compensation be provided to victims of lung cancer that can reasonably be attributed to working in the uranium mines.

The Workmen's Compensation Board first allowed compensation for lung cancer among uranium miners in 1970. As shown in Table 5, eight out of thirty-one cancer cases charged to the mining industry in 1974 were uranium miners. The cases of lung cancer among uranium miners allowed compensation to the end of 1975 total twenty. The compensation almost invariably has been as a pension to the widow and family.

The difficulties inherent in deciding which cases are entitled to compensation have been outlined in the subsection on Work Adjustment. There is, on the basis of medical evidence, no clear way to identify the subset of persons within the total number of cancer deaths whose deaths represent the statistical excess over that number which would be expected in the absence of exposure. Exposure alone is not a definitive determinant. The act of granting compensation is a human decision and not susceptible to

sharp quantitative prescription. In effect the Board is placed in the unenviable position of judging which persons may be considered to have been at exceptional risk. There is an inescapable dilemma here. On the one hand most of the persons on the Uranium Nominal Roll who have died of lung cancer have experienced some additional risk by exposure to radiation in the mines. On the other hand it is statistically clear that half of these persons would have experienced lung cancer in any event. There are certain guiding principles to be recommended beyond which, the Commission believes, the Board should give every reasonable benefit of doubt to the man and his family. First, it is recommended:

That the Workmen's Compensation Board of Ontario, in collaboration with other provincial boards as provided for in interprovincial agreements, seek out and advise the families of all ascertained deaths due to lung cancer on the Nominal Roll that a claim for compensation should be entered.

The Board should review all claims for compensation using the following as evaluative factors in the adjudication: 1/ the duration of the period of exposure to dust and ionizing radiation, 2/ the record of cumulative exposure to ionizing radiation and the limits of variability anticipated in this record, 3/ the elapsed time from entry to illness or death, 4/ the environmental record at the mines worked at and the jobs undertaken, 5/ the calendar years spanning the interval of exposure, 6/ the age at entry, 7/ the pathology of the primary tumour, 8/ the available analysis of the mortality experience of the Ontario Uranium Nominal Roll, 9/ the available estimates of risk of lung cancer for the Ontario Uranium Nominal Roll, and 10/ the record of factors of risk known to be conjoint with ionizing radiation, and the related evidence on the role of radiation.

With regard to item 10 it has been noted that had no uranium miners smoked cigarettes the number of observed cancer deaths expected would have been very much smaller. This fact may be used to argue that the excess of lung cancer is in some sense due largely to cigarette smoking and therefore that the number of persons compensated should be reduced accordingly or charged to the Consolidated Revenue Fund rather than to the uranium mines. The manner in which radiation exposure combines with cigarette smoking to produce a resultant risk of cancer is not clearly understood at the levels of exposure experienced in Ontario mines. In the matter of compensation, the Commission's view, which is not based on scientific premises, is that uranium miners should be compensated without

regard to their smoking habits, because they experience a greater risk than the smoking non-miner.

Should evidence be obtained that there is a threshold of exposure to ionizing radiation below which there is no risk of lung cancer from this cause, the evaluative criteria of the Board ought to be altered accordingly. However, the argument for such a threshold must be demonstrated to be consistent with data obtained from the Ontario uranium mines and their workers. Whether or not there is such a threshold or some unknown carcinogen, there is excess lung cancer, for which compensation must be provided on a generous basis of interpretation. The costs of nuclear power for public use are so vast that the costs of being publicly responsible to uranium miners and their families are by comparison negligible.

1 *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: Report of the Advisory Committee on the Biological Effects of Ionizing Radiation. Division of Medical Sciences, National Academy of Sciences and National Research Council*, Washington DC, November 1972, chap. 7 and appendix 7, f Lung; Henceforth cited as BEIR *Report*. Frank E. Lundin jr, Joseph K. Wagner, and Victor E. Archer, *Radon Daughter Exposure and Respiratory Cancer Quantitative and Temporal Aspects: National Institute for Occupational Safety and Health, National Institute of Environmental Health, Joint Monograph No. 1*, Washington DC, June 1971, chap. 3; henceforth cited as Lundin et al., *Radon Daughter Exposure*

2 Lundin et al., *Radon Daughter Exposure*, 97

3 Victor E. Archer, Geno Saccomano, and James H. Jones, 'Frequency of different histologic types of bronchogenic carcinoma as related to radiation exposure,' *Cancer*, 34, 1974, 2056–60

4 Extensive statistical analysis of the occurrence of lung cancer among uranium miners in the United States is available and developed in the following institutional sources: Lundin et al., *Radon Daughter Exposure*; Advisory Committee from the Division of Medical Sciences: National Academy of Sciences, National Research Council, National Academy of Engineering, *Radiation Exposure of Uranium Miners*, Washington DC: Federal Radiation Council, August 1968; Federal Radiation Council, *Guidance for the Control of Radiation Hazards in Uranium Mining*, Washington DC: F.R.C. Report No. 8 (Revised), September 1967

5 Lundin et al., *Radon Daughter Exposure*, Tables 4, 5

6 Victor E. Archer, Joseph K. Wagoner, and Frank E. Lundin, jr, 'Uranium mining and cigarette smoking effects on man,' *Journal of Occupational Medicine*, 15, 1973, 204–11; Victor E. Archer, Dean J. Gillam, and Lynn A. James, 'Respiratory disease mortality among uranium miners as related to height, radiation, smoking, latent period,' to appear in the forthcoming *Proceedings of the Third International Symposium on the Detection and Prevention of Cancer*, ed. H.E. Nieburgs, MD, New York, 1976

7 P. Gross and R.T.P. de Treville, 'The pneumoconioses,' *The Industrial Hygiene Foundation of America, Bulletin No. 12*, 1967; I. Webster, 'Bronchogenic carcinoma in South African gold miners,' *Pneumoconiosis, Proceedings of the International Conference*, Johannesburg, 1969, 572–4; E. Trapp et al., 'Cardiopulmonary function in uranium miners,' *American Review of Respiratory Disease*, 101, 1970, 27–43; J. Chameaud et al., 'Risques et nuisances des mines d'uranium prevention medicale,' *Colloque International de Radioprotection dans l'Extraction et Le Traitement de L'Uranium et du Thorium*,

Bordeaux, France, 9–11 septembre 1974; see also n 6. Archer et al., 'Respiratory disease mortality'.

8 There are three major chains for which the parent isotopes are U^{238}, U^{235} and Th^{232}. Of all the uranium, 99.3 per cent is U^{238} and 0.7 per cent U^{235}. For details of the chains see, for example, G. Friedlander and J.W. Kennedy, *Nuclear and Radiochemistry*, New York, 1955, chapter 1, sec. C.

9 A.J. Villiers and J.P. Windish, 'Lung cancer in a fluorspar mining community – 1 radiation, dust and mortality experience,' *British Journal of Medicine*, 21, 1964, 94–108; Newfoundland, Royal Commission Respecting Radiation, Compensation and Safety in the Fluorspar Mines, St Lawrence, Nfld, *Report*, Newfoundland: Queen's Printer, 1969; J.K. Wagoner et al., 'Unusual cancer mortality among a group of underground metal miners,' *New England Journal of Medicine*, 269, 1963, 284–9 (Radiation levels are estimated to have been between 6 and 24 WLM per annum.); J.O. Snihs, 'The approach to radon problems in non-uranium mines in Sweden,' *Proceedings of the Third Conference of the International Radiation Protection Association*, Washington DC, September 1973; H.S. Jorgensen, 'A study of mortality from lung cancer among miners in Kiruna 1950–1970,' *Work Environmental Health*, 10, 1973, 126–33; Karl Göran St Clair Renard, 'Respiratory cancer mortality in an iron mine in Northern Sweden,' *Ambio*, 3, 1974, 67–9; M.J. Duggan et al., 'The exposure of United Kingdom miners to radon,' *British Journal of Industrial Medicine*, 17, 1970, 106–9; J.C. Strong, A.J. Laidlaw, and M.C. O'Riordan, *Radon and Its Daughters in Various British Mines,* London: National Radiological Protection Board, Report 39, HMSO, 1975; J.K. Basson et al., 'Lung cancer and exposure to radon daughters in South African gold/uranium mines,' *4th International Conference on the Peaceful Uses of Atomic Energy*, Geneva, 1971

10 The biological significance of rare earths in mine aerosols is not clear, but the distinctive variations noted deserve attention in research related to the proposed statutory standard for dust. Yttrium and cerium metallic compounds are common. The significance of free silica has been discussed in chapter 2.

11 United States Public Health Service, *Control of Radon and Radon Daughters in Uranium Mines and Calculations of Biologic Effects*, Washington DC: US Department of Health, Education and Welfare, Public Health Service Publication No. 494, 1957 (henceforth cited as US Public Health Service Publication 494); Duncan A. Holaday, *Evaluation and Control of Radon Daughter Hazards in Uranium Mines*, Washington DC: US Department of Health, Education and Welfare, No. [NIOSH] 75-117, November 1974

Only 0.7 per cent of uranium atoms are of the isotope U^{235}, and the half-life of the gas actinon, which appears in its radioactive chain, is 3.92 seconds, as compared to 3.83 days for radon. Thus there is very little actinon, compared to the amount of radon, and only a relatively small fraction of that becomes airborne.

In Ontario uranium ores, the number of atoms of thorium Th^{232} which give rise to the gas thoron is comparable to the number of atoms of uranium. However, the half-life of thorium is about three times that of uranium U^{238} and the half-life of thoron gas is about 1/6000 of that of radon gas. Both of these factors diminish significantly the amount of thoron that becomes airborne in mine air relative to the amount of radon. Further, the relatively long half-life of the daughter Thorium B facilitates it being swept out by ventilation. For a comparative analysis of the effects of radon and thoron at a given activity level in relation to a lung model see for example, W. Jacobi, 'Relations between the inhaled potential α – energy of Rn^{222} – and Rn^{220} – daughters and the absorbed α – energy in the bronchial and pulmonary region,' *Health Physics*, 23, July 1972, 3–11. For related sampling analysis, see for example R.L. Rock, *Sampling Mine Atmospheres for Potential Alpha Energy Due to the Presence of Radon –220 (Thoron) Daughters*, Denver: Mining Enforcement and Safety Administration, Information Report IR-1015, 1975. M.J. Duggan, 'Some aspects of the hazard from airborne thoron and its daughter products,' *Health Physics*, 24, March 1973, 301–10; J.C. Strong and M.J. Duggan, 'The effects of the

presence of thoron daughters on the measurement of radon daughter concentrations,' *Health Physics*, 25, September 1973, 299–300

12 A few measurements of thoron daughters were made in the Rio Algom Nordic Mine by the Ministry of Health in August 1967.

13 Beta rays are high speed electrons, gamma rays are similar to X-rays, and alpha particles are energetic nuclei of helium atoms. Alpha particles penetrate at most a few surface layers of human cells; beta and gamma rays are more penetrating, and the latter in particular contribute to whole-body irradiation.

14 The gamma and beta irradiation is in part from uranium and thorium in the faces of the unbroken and broken rock and in part from the daughters of radon and thoron in the mine air.

15 The radiation dose in Rems (Roentgen Equivalent Man) is equal to the absorbed energy dose in Rads times the RBE (Relative Biological Effectiveness) factor for the type of radiation being absorbed. The Rad is a measure of the energy of irradiation absorbed by a unit mass of human cells and is 0.01 joules per kilogram. The RBE factor is relative to the biological effect of one Rad of 250 KV X-rays (BEIR *Report*).

16 At the time of writing the Atomic Energy Control Board had not formally designated uranium miners as Atomic Radiation Workers under the Atomic Energy Control Act, but Schedule II, which is based on the recommendations of the International Commission on Radiation Protection (ICRP), has been used by the mines as a guide.

17 A.J. Breslin, A.C. George, and M.S. Weinstein, *Investigation of the Radiological Characteristics of Uranium Mine Atmospheres*, New York: Health and Safety Laboratory, US Atomic Energy Commission, HASL-200, December 1969, 24 (henceforth cited as Breslin et al., *Investigation*)

18 The natural background irradiation plus medical diagnostic irradiation of the general population in the USA average about 0.170 Rems per year. BEIR *Report*, Table 1, 50

19 US Public Health Service Publication 494, 15–20

20 The special role of radon daughters was first identified by W.F. Bales in 1951 in an unpublished memorandum of the US Atomic Energy Commission, entitled 'Hazards associated with radon and thoron.'

Radon gas breathed into the lungs contributes also to a body burden of radioactive substances by diffusing through the alveolar membrane into the blood from which it deposits preferentially in fatty tissues. Further, mine dust contains radioactive uranium and thorium products deriving from the stages of the decay chains which precede the noble gases and follow the basic daughters. A maximum permissible limit on this component of radiation is in use in the French uranium mines, together with limits on external radiation and internal radiation from radon and its daughters. Y. François, J. Pradel et P. Zettwoog, 'Incidence des normes de radioprotection sur le marché de l'uranium,' in *Radon in Uranium Mining*, Vienna: International Atomic Energy Agency, 1975

21 The level of radioactivity in mine air is one 'Working Level' when the complete decay to Radium D of whatever combination of short-lived daughters of radon Rn^{222} is present in one litre of air would yield a total Alpha energy of 1.3×10^5 MEV. A 'Working Level Month' is exposure for 170 hours to mine air in which the radioactivity averages one Working Level over that period.

22 *Code of Requirements for the Survey of Dust, Ventilation and Radioactivity at Uranium Mines in Ontario, Department of Mines*, Ontario, 1 March 1957; Mines Accident Prevention Association of Ontario, *Radon Daughter Sampling Procedure*

23 Mines Accident Prevention Association et seq., *First Report – Dust Control, Ventilation and Radioactivity at Faraday Uranium Mines Limited*, January 1956. The accepted standard of radioactivity in mine air was equivalent to 100 picocuries per litre of each of the radon daughters Radium A, B, and C in equilibrium. One picocurie is equal to 2.22 nuclear disintegrations per minute. W.E. Bawden, 'Proposed legislation on radioactivity by Department of National Health and Welfare of Ottawa,' Memorandum to Dr C.G. Cunningham, Division of Industrial Hygiene, Department of Health, 5 Aug. 1959, Toronto

24 *Radiation Hazards in Ontario Mines*, Department of Mines, 4 Dec. 1967
25 *Radiation Exposure in Ontario Mines*, Ministry of Natural Resources, Mines Division, Engineering Branch, 9 Nov. 1972
26 *Radiation Exposure in Ontario Mines*, Ministry of Natural Resources, Division of Mines, Mines Engineering Branch, 1 July 1974
27 Unfortunately, as so often happens with occupational health records, there was no requirement that these new records be readily linkable with the massive existing radiographic records maintained by the Workmen's Compensation Board.
28 For representative membership, see Ontario Mining Association, *Annual Report*, 1973.
29 For example, W.C. Wheeler, 'Progress report on the preparation of a nominal roll of Uranium miners,' presented at Advisory Committee on Occupational Health of the Ontario Mining Association, 23 Nov. 1972
30 The origin and stages of development of the initial Nominal Roll are described in J. Muller and W.C. Wheeler, 'Causes of death in Ontario uranium mines (Second report), May 1974, revised July 1974 (hereafter cited as Muller and Wheeler, 1974).
31 These estimates were based on proportional mortality ratios. The form of the Nominal Roll was not, and is not, sufficiently complete to permit ready calculation of either man years at risk or of personal radiation exposure, and the death search was for Ontario records only.
32 Jan Muller, 'Causes of death in Ontario uranium mines' (Preliminary Report), January 1973. Prior to this report, reference had been made to the identification of twenty cases of lung cancer among uranium miners. See Ministry of Health, *Occupational Health in Ontario*, 22, December 1970, 5.
33 Muller and Wheeler, 1974
34 J. Muller, W.C. Wheeler, 'Causes of death in Ontario uranium miners,' *Proceedings of the International Symposium on Radiation Protection in Mining and Milling of Uranium and Thorium*, Bordeaux, France, 9–11 September 1974
35 Transcript of hearings, 566
36 In response to an internal review of the field of occupational and environmental health conducted by the government in 1975, an Advisory Committee on Occupational and Environmental Health comprising representatives of industry, labour, and government and advisory to the Ministry of Health, has been established.
37 D. Hewitt, 'Radiogenic lung cancer in Ontario uranium mines, 1955–1974,' Commission Project Document, May 1976. Data not reviewed in the report are included in appendix C.
38 Man-years at risk were estimated from a 10 per cent random sample of the Nominal Roll. The sample was determined by selecting persons whose Miner's Certificate numbers ended in the digit 4. The random sample of cumulative exposure to radiation was conducted for 1 per cent of the Nominal Roll and yielded 158 persons, of whom 147 were survivors to the end of 1974. The sample was determined by selecting persons whose Miner's Certificate numbers ended in the digits 34.
39 There is no assured manner in which to determine whether or not *all* deaths have been found. An analysis of the yield of data from the previous Ontario searches and from the computer-based search of Statistics Canada leads to an estimate that about 115 deaths may not yet have been found, including proportionately more deaths at ages over fifty years than among the 956 successfully 'ascertained' deaths. Such a possible deficit in observed deaths would not alter the conclusions of this study. If the deficit is of the size and type suggested, the total number of deaths to the end of 1974 would be about 1070 (see Table 23), and lung cancer deaths would be about ninety-three rather than eighty-one. It is further assumed that no incorrect matches have been made. The assessment herein then is given as if 956 and 81 represent all deaths.
40 Another choice for comparison is the population of Northern Ontario. The Commission has examined the relation of the actual death-experience of males in Northern Ontario to expected deaths among all Ontario males. The comparison is shown in Table D.9. This table is for all ages, whereas ages over 65 are largely unrepresented at present in the

Nominal Roll. A further comparison population worth considering is an age-matched group of non-uranium miners. The comparison with all Ontario males as used by the Commission serves to illuminate the public health risks of uranium mining.

41 Expected deaths are based on the man-years at risk in the entire Nominal Roll, which includes many persons with very short working exposures. The actual deaths are based on the best achievable search. Since some deaths may be missed, the figures for actual deaths are conservative. Thus, while the ascertained excess of cancer deaths is thirty-six, an estimate based on the effectiveness of the search leads to the number forty-eight. The expected number at 45.08 is statistically complete within a sampling error on man-years at risk.

42 Epidemiological research on the risk of cancer at a future time produced by a present exposure to radiation may permit the course of the excess of lung cancer to be estimated. See Lundin et al., *Radon Daughter Exposure*, chap. 4.

43 The mortality experience of US uranium miners reveals some distinctive differences from that of the Ontario Uranium Nominal Roll. See Victor E. Archer and Joseph K. Wagoner, 'Lung cancer among uranium miners in the United States,' *Health Physics*, 25, October 1973, 351–71 and Table 1 (hereafter cited as Archer and Wagoner, 1973).

44 In Table 23 the comparison is between expected and estimated actual deaths (rather than ascertained deaths). See n. 39.

45 BEIR *Report*.

46 See n. 4 and C.D. Stewart and S.D. Simpson, 'The hazards of inhaling Radon-222 and its short-lived daughters: considerations of proposed maximum permissible concentrations in air,' in *Radiological Health and Safety in Mining and Milling of Nuclear Materials*, Vienna: International Atomic Energy Agency, 1964, 333–57

47 For comparable US case data see Archer and Wagoner, 1973, Table 5. The mean exposure of 115 cases of cancer in US uranium mines was 2,000 WLM.

48 The control group of eighty-one randomly selected survivors was determined from the 1 per cent sample (see n. 38) by deleting deaths and ensuring that the date of birth was such as to enable the person to have been employed in the mines in 1954–5 and later.

49 See appendix C, D. Hewitt, 'Radiogenic cancer in Ontario uranium mines, 1955–1974.' Table C.1 and Figure C.1 refer to tests of dependence on cumulative exposure, Table C.2 to tests related to region of employment and period of entry, and Table C.3 to a test for dependence of radiation effects on age.

50 The Atomic Energy Control Act of the federal government was passed in 1946 and first revised in 1954.

51 *Atomic Energy Control Regulations P. C. 1960-348*, 94 (*Canada Gazette, Part II, SOR 60/119, April 13, 1960*). The most recent revision was in 1974 under PC 1974-1195, 108 (*Canada Gazette, Part II, SOR/DORS 74-334, June 26, 1974*).

The 1960 Regulations were reviewed with provincial authorities before enactment. Under these Regulations certain members of the staff of the Mines Engineering Branch were designated radiation inspection officers by the federal Department of Health and Welfare on behalf of the Atomic Energy Control Board. The practice continues and the Board offers a Uranium Mine Inspector Training course.

The AECA Regulations stipulate maximum permissible doses of ionizing radiation in Rems per annum. However, no interpretation of internal alpha irradiation in terms of equivalent values of practical units such as the Working Level Month has formally been given by the Board. In the hearings of the Commission, the AECB contended that the limit of 15 Rems per annum to the lung may be considered to have been met by the provincial standards ranging from 12 to 4 WLM (Transcript, 5449).

52 Federal Radiation Council, *Guidance for the Control of Radiation Hazards in Uranium Mining*, Washington DC: F.R.C. Report No. 8 (Revised), 1967. The Board's response is described in the Transcript 5406 ff.

53 *Revised Statutes of Canada, 1970*, First Supplement, c. 22.

54 *Pronto Uranium Mines Limited and Algom Uranium Mines Limited* v *The Ontario Labour Relations Board et al., Ontario Reports* (1956), 862. *Denison Mines Limited* v *The Attorney General of Canada, Dominion Law Reports* (1972), 419
55 *Revised Statutes of Canada*, 1970, c. G8
56 Transcript, 5402, 5411. For difficulties with provincial authorities see 5424–5.
57 See nn. 58, 59, and F.T. Cross et al., 'Evaluation of methods for setting occupational health standards for uranium miners,' *Report PB-237 774*, np: Battelle-Pacific Northwest Laboratories, March 1974; Available from NTIS, US Department of Commerce.
58 'Recommendations of the International Commission on Radiological Protection (Revised December 1954),' *British Journal of Radiology*, Supplement No. 6, London, 1955. The ICRP recommendation of 100 picocuries per litre of radon and its daughters for a 168-hour week came to be interpreted in Ontario as 100 picocuries per litre of each of the daughters RaA, RaB, and RaC for a 40–50 hour week. Under equilibrium conditions, 100 picocuries per litre of each of the latter daughters is equivalent to 1 Working Level. An instrument based on a scintillation counter to detect alpha disintegrations was designed with the assistance of Atomic Energy of Canada Ltd and manufactured in Canada. Over a period of a few minutes this instrument sucks several litres of mine air through a filter on which radioactive particles accumulate for subsequent reading of the rate of nuclear disintegration. The method of measurement adopted was that due to Kusnetz in H.L. Kusnetz, 'Radon daughters in mine atmospheres – a field method for determining concentrations,' *American Industrial Hygiene Quarterly*, 17, March 1956. Until 1967, readings were recorded in equivalent equilibrium picocuries/litre rather than in Working Levels. See also n. 23 and A.J. Cipriani, 'Radiation hazards in uranium mines,' *Proceedings of Technical Sessions of the 24th Annual Meeting of the Mines Accident Prevention Association of Ontario*, May 1955; and G.R. Yourt, 'Sampling for radioactivity in uranium mines,' *Proceedings of Technical Sessions of the 24th Annual Meeting of the Mines Accident Prevention Association of Ontario*, May 1955.
59 International Commission on Radiological Protection, *Report of Committee II on Permissible Dose for Internal Radiation (1959)*, London: ICRP Publication No. 2, 1960
60 'Radiation hazards in uranium mines, with particular attention to the ICRP II (1959) revision of the guide level for radon and radon daughters,' *Minutes of a Conference, Department of Mines, Department of Health*, Toronto, 3 Nov. 1960. The Atomic Energy Control Board was not represented at this meeting.
61 The 30-picocurie per litre standard for a 40-hour week or 3.6 Working Level Months (rounded to 4 WLM) did not become effective under a code of requirement issued by the Mines Engineering Branch until January 1975.
62 For example, the following sources affirmed the 12 WLM per annum standard: 'Radiation protection in uranium mines and mills,' *USA Standards Institute Document USAS N7.1-1960*, 3 Oct. 1960; US Public Health Service, *Governors' Conference, Health Hazards in Uranium Mines*, Washington DC: Department of Health, Education and Welfare, US Public Health Service Publication No. 843, 1961 (An increased lung cancer risk among US uranium miners was first documented at this conference.); 'Radiation protection guide for federal agencies,' Federal Radiation Council, USA, in the *Federal Register*, 32, No. 7, Tuesday, 1 Aug. 1967; US Department of Interior, 'Regulations pursuant to the Federal Metal and Nonmetallic Safety Act,' *Federal Register*, 34, No. 11, Thursday, 16 Jan. 1969. For further detail of US practices see n.57, Cross et al. In the USA, issues related to federal and state jurisdictions have been more complex than the corresponding federal and provincial question in Ontario. Provisions for variances from stated standards have been common. A Congressional examination of conditions in US mines is reported in *Radiation Exposure of Uranium Miners: Hearings Before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, Congress of the United States*, Washington, 1967.
63 This revision was in response to concern expressed by the Atomic Energy Control Board

(see n.52). It included a new requirement for the maintenance of individual exposure records. After endorsement by the industry through the Ontario Mining Association it was issued as a code by the Chief Engineer of the Mines Engineering Branch (see n.24).

64 Metal and Non-Metal Mine Health and Safety Standards and Regulations, Public Law 89-577, *Federal Metal and Non-Metallic Mine Safety Act*, Section 57.5-38, as superseded effective July 1, 1971, under a ruling of the Environmental Protection Agency, Mining Enforcement and Safety Administration, Washington, October 1974

65 Transcript, 4234–5, 5567, and 4622, respectively

66 C.G. Stewart, 'A history of the development of radiation protection,' unpublished manuscript communicated to the Commission in July 1975 (cited hereafter as Stewart, 1975)

67 International Commission on Radiological Protection, *Recommendations*, London: ICRP Publication No. 9, 1966

68 J. Muller, 'Criteria for radon daughter concentrations in uranium mines,' Ontario, Ministry of Health, May 1975 (cited herafter as Muller, 1975)

69 Lundin et al., *Radon Daughter Exposure*, 89

70 See n.20, François et al.

71 See for example A.C. Chamberlain and E.D. Dyson, 'The dose to the trachea and bronchi from the decay of products of radon and thoron,' *British Journal of Radiology*, 29, June 1956, 317–25. See also n.11, Jacobi, 1972, and H. Parker, 'The dilemma of lung dosimetry,' *Health Physics*, 16, 1969, 553.

72 See n.57, Cross et al., Table 2.2.

73 Representative conversion factors as used in the BEIR *Report* and in Lundin et al., *Radon Daughter Exposure*, are 1 WLM = 2 Rads = 5–6 Rems.

74 Transcript, 5449

75 See n.4. For a compilation of related sources see n.57, Cross et al.

76 Lundin et al., *Radon Daughter Exposure*, Tables 4–7.

77 Ibid., Chapter V sect. H, 112. See also the conclusions in the works cited in nn.6 and 43.

78 Ibid., sect. I, 112

79 C.G. Stewart and S.D. Simpson, 'On an (MPC) a for the short-lived daughters of Rn222 – 1969,' *Pneumoconiosis, Proceedings of the International Conference*, Johannesburg, 1969

80 See n.9, Jorgensen, 127, 132, and Snihs.

81 See n.9, Basson et al., 9. The epidemiological data as published are incomplete; see also ibid., Jorgensen, 132.

82 See n.7, Chameaud et al., 5–6. The number of underground workers increased to 1000 in 1958 and was 600 in 1974. Some 450 have more than fifteen years experience underground, and, of these, 300 have more than eighteen years, and 100 have more than twenty years. Eleven cases of lung cancer have been found, of which two had exposures of about 300 WLM, three of between 150 and 100 WLM, and the remaining six of between 10 and 50 WLM.

83 There are no occupational records available for persons on the Nominal Roll after they cease to report in Ontario for the annual examination required to maintain a valid Miner's Certificate.

84 G.R. Yourt, *Radiation in Ontario Non-Uranium Mines*, np: Mines Accident Prevention Association of Ontario, 11 Dec. 1961: a survey of five gold mines. Peter Chmara, *Surveys of Radioactivity in Non-Uranium Mines*, Toronto: Mines Accident Prevention Association of Ontario, 3 Dec. 1975: surveys of sample workplaces throughout the industry.

85 Department of National Health and Welfare, Environmental Health Directorate, Health Protection Branch, *Radon Daughters and Dust Measurement Practices in Elliot Lake Uranium Mines: A Report to the Division of Mines, Ontario Ministry of Natural Resources*, Ottawa, March 1974.

86 Ontario Ministry of Health, *Survey of Dust, Radiation and Diesel Exhaust In Uranium Mines and Mills at Elliot Lake, Ontario*, Toronto, 29 Nov. 1974.

87 See n.6 for United States data on the effects of smoking. A recent survey of uranium

miners at Elliot Lake found that some 60 per cent of them smoke and 24 per cent are former smokers. Smoking was forbidden underground under a code of the Mines Engineering Branch as of 1 Jan. 1973. (see chap. 2, n. 24).

88 C. Starr, 'Social benefit versus technological risk,' *Science*, 165, 1969, 1232–8; R.H. Mole, 'Ionizing radiation as a carcinogen: practical questions and academic pursuits,' *British Journal of Radiology*, 48, March 1975, 157–69

89 Lundin et al., *Radon Daughter Exposure*. Conclusion M (113) states in part that 'there is, therefore, no scientific reason to suspect that dose-rate has influenced the respiratory cancer risk among miners exposed in the 120 to 360 WLM range.'

90 Ibid., chap. 4; see Table C.2 for a related statistical test conducted as part of the sample analysis by the Commission.

91 US Bureau of Mines, *Information Report IR 8036* (1975). Control of radon emanations and related matters are extensively discussed in *Radiation Protection in Uranium and Other Mines*, Report of the International Commission on Radiological Protection (to be published).

92 The uranium mines currently are pumping on the order of 160,000 cubic feet per minute of ventilation air per ton of ore hoisted per day. This figure is about twice that in use in the gold mines (see Tables D.2 and D.3).

93 R.D. Lord and P.F. Pullen, 'A proposal for monitoring mine ventilation air volumes,' *Canadian Institute of Mining Transactions*, 74, 1971, 229–36. Such systems have been designed in Finland.

94 See, for example, G.K. Greenough, 'The dust helmet – protection for head, eyes and lungs,' *Underground Services* 2, London, 1974 and Safety in Mines Research Establishment, 'Respirable Dust – 3,' *Digest*, 1974 (Sheffield)

95 Safety Guide For Respiratory Protection Against Radon Daughters, *American National Standard*, New York: ANSI Z288.1 – 1969, 1969.

96 Geno Saccamanno et al., 'Development of carcinoma of the lung as reflected in exfoliated cells,' *Cancer*, 33, Jan. 1974, 256–69

97 W. Clark Cooper and Michael D. Utidjian, 'The role of sputum cytology in occupational medicine,' *Proceedings of XVII Congress on Occupational Health*, Buenos Aires, Sept. 1972; W. Clark Cooper, *The Role of Sputum Cytology in Occupational Medicine: Supplementary Report*, np: NIOSH HSM-099-71-51, March 1975.

98 Elliot Lake Sputum Cytology Programme; Sputum Cytology Programmes, 1973 and 1974, Ministry of Health (Ontario), Exhibit Number 139 before the Commission. No confirmed case of malignancy was discovered in the population of some two hundred persons screened at Elliot Lake.

99 The Mines Engineering Branch has examined the cumulative radiation exposures of 464 persons who were employees in the Elliot Lake Mines in 1974 and had entered these mines prior to 1968, the year in which personal exposure records were initiated. Of these persons, 159 had exposures in excess of 120 WLM and 61 had exposures in excess of 240 WLM. The highest exposure of one person was in the range 301–21 WLM.

100 *Early Detection of Health Impairment in Occupational Exposure to Health Hazards*, Geneva: WHO, Technical Report Series 571, 1975; *Environmental and Health Monitoring in Occupational Health*, Geneva: WHO, Technical Report Series 535, 1973

101 Mining Act, Part IX, Section 167

102 Ibid., Subsection 1 (c), and Department of Mines and Northern Affairs, *Memorandum Re Surface Dust Exposure Occupations*, Mines Inspection Branch, 15 Dec. 1967; Mining Act, Part IX, Section 167, Subsection 6

103 It is worthy of note that a miner may retain a Miner's Certificate while displaying any respiratory abnormalities other than tuberculosis and, in particular, silicosis.

104 H.B. Newcombe, *A Method of Monitoring Nationally For Possible Delayed Effects of Various Occupational Environments*, Chalk River: National Research Council, Associate Committee on Scientific Criteria for Environmental Quality, 1974

4

Accidents and injuries

INTRODUCTION

Accidents are unexpected and individually unpredictable events whose origins involve a complex set of factors, human and technical.[1] They occur when unrecognized adverse conditions, present at the workplace or created by the manner in which work is organized, supervised, or carried out, lead to undesired consequences in the form of injuries to persons, damage to equipment, and loss of production.

Accidents at mines and plants arise in relation to 1/ the movement of persons and materials to and from the workplace, 2/ the nature of the workplace, 3/ the materials, tools, machines, and processes associated with the workplace, and 4/ work methods and the performing of work. An example of each type of accident is as follows: 1/ being struck by an ore-haulage train, 2/ a fall of rock from the roof of a development heading, 3/ the tipping over of a load-haul-dump machine while ore is being moved, and 4/ the fall of a miner down an open mill hole.

Each of these accidents may be associated with one or more anomalous conditions which may lead to a variety of consequences. A haulage train may move unexpectedly (for the injured workman) when there is unclear communication between the operator and persons in the vicinity of the train. Operating procedures as well as signalling devices may be faulty. An unintended fall of ground may be a massive structural movement of rock associated with variations in local geology and the design of the mine openings being driven; or it may occur on a smaller scale, for example when production commences before adequate standards of protective scaling, bolting, and screening have been applied. A load-haul-dump machine may be used in an unintended manner or may be defective for

want of regular maintenance in some operational characteristic such as steering. A miner may fall down an ore pass through failing to notice the hazard when alone or while activity is in progress around him. In each of the foregoing accidents the human consequences may range from nil to fatality.

In the hearings before the Commission there were two particular points of emphasis in relation to accidents, unsafe conditions and unsafe acts. Some workers' representatives emphasized the former, and some management representatives the latter. Unsafe conditions may have their origin in unclearly defined and communicated management objectives. They may arise through defects of plant and mine design, through methods of work inadequate in themselves or inadequately supervised, and through tools, equipment, and processes inadequately maintained. Unsafe acts of any person may originate in want of vigilance, training, skill, physical strength, or judgment when all conditions of work are otherwise within standards. In many respects the details of Part IX of the Mining Act represent the lessons of historical experience in the form of regulatory standards intended to eliminate the roots of many unsafe conditions and unsafe acts.

The Commission believes that emphasis on unsafe conditions and unsafe acts falsely dichotomizes and greatly oversimplifies the organic circumstances out of which accidents arise. Thus, the major prospect for reducing the adverse human consequences of accidents may lie in increasing the commitment and capacity of all persons in the organization to detect and to correct anomalies of operation that contribute to accidents. The basis for such action lies in effective training and supervision and in co-operative understanding of the complementary processes of what will be called internal and external 'auditing.' This chapter studies the pattern of injuries arising from accidents in Ontario mines, and examines the roles of the various parties in detecting and dealing with the functional anomalies of operation that cause accidents.[2]

THE CLASSES OF INJURIES ARISING FROM ACCIDENTS

Injuries arising from accidents in the mining industry are categorized as first-aid, medical-aid, light-duty, non-fatal compensable, and fatal. In this chapter statistical data on non-fatal compensable injuries and on fatal injuries will be reported, but it is important to understand their relation to events of lesser or related human consequences. First-aid injuries involve

minor cuts, bruises, and so on that can be dealt with at a first-aid station at the mine or plant and entail no loss of time at work. But such accidents may be as indicative of anomalies in operations as those involving more serious injuries. Medical-aid injuries are those requiring the services of an attending physician commonly outside the premises of the mine. However, they do not involve loss of time at work other than on the day of the accident. (The characteristics of medical-aid injuries involving accidents with chemical substances are reviewed in chapter 5.) Medical-aid injuries are reported to the Workmen's Compensation Board for payment of medical fees. The Mines Accident Prevention Association maintains no statistical record of these events.

Light-duty and non-fatal compensable injuries possess in common the fact that the person injured does not return to his or her regular place of work for at least one day following the date of the accident. Under current procedures of record-keeping in the industry an injury becomes non-fatal compensable when the eligible worker receives from the Workmen's Compensation Board the whole or part of his current wages for at least one day following the date of the related accident. Statistics on this class of accident and on fatal accidents are maintained by the Mines Accident Prevention Association from records of the Workmen's Compensation Board. A simple compensable injury causes the workman to remain away from work until he is able to return to his regular job. Under these circumstances he receives from the Workmen's Compensation Board 75 per cent of his regular wage rate provided it does not exceed a rate of $15,000 per annum.

A light-duty injury is so defined when a company assigns an injured workman, with the concurrence of an attending physician, to other work for some period before he returns to his regular job. If the rate of pay for the newly assigned work is identical with the person's regular rate of pay no compensation from the Workmen's Compensation Board is involved and no record of the injury enters the statistics maintained by the Mines Accident Prevention Association through information supplied to the Board. If the company pays its regular rate for the type of work undertaken by a person on light-duty assignment, and this rate is less than the person's regular wages, the Workmen's Compensation Board pays 75 per cent of the difference, the injury being classed as compensable and entering the statistics of the Mines Accident Prevention Association.[3]

During the hearings of the Commission two disturbing facets of light-duty work assignments became apparent: the possibility of non-uniform standards in the recording of injury statistics within the industry[4] and the

objection of some union representatives to the principle of rehabilitation that underlies such assignments.[5] To ensure consistency in statistical records and to ensure that the workman's basis for eligibility for subsequent compensation is protected by the establishment of an appropriate record, the Commission recommends:

That the Workmen's Compensation Board require and make provision for the inclusion in non-fatal injury statistics of all non-fatal injuries in which the injured person fails to return to his or her regular job on the day following the date of the accident giving rise to the injury.

The principle of rehabilitation, that is, of assisting an injured worker to return as soon as possible to regular work, has been basic to the Workmen's Compensation Board and is surely a desirable objective. It is disturbing therefore to find union representatives alleging that light-duty may be used by companies to conceal injuries that would otherwise be entered as compensable and implying that a person's recovery might by engaging in such work be delayed beyond what it would be if the person simply remained away from work. This is one of several areas of tension between some unions and management that can be removed by openness. It has already been recommended that the issue of consistency of records be clarified; the Commission further recommends, as one area for co-operation between workers and management on Health and Safety Committees:

That management inform the Joint Health and Safety Committee about its policies on rehabilitative work assignment and in the context of independent medical consultation seek the advice of the Committee in giving wise effect to its policies.

Since both parties desire the good of the individual worker, confrontation can and must be set aside with respect both to accidents and to health-impairing environmental exposures. The best interests of a workman may be served by rehabilitative work adjustment on a temporary basis.

The statistical record of fatal injuries and of non-fatal compensable injuries in the industry will now be examined and placed in perspective with experience in other jurisdictions. A summary of Ontario records for 1974 has been given in Tables 3 and 4.

TABLE 27

Fatal injuries in metal and non-metal mining companies in Ontario 1965–75

Calendar year	Man-hours worked[a] (millions)	Man-years at risk[b] (N)	Fatalities[c] (N)	Fatalities per 10,000 man-years at risk (N)	Fatalities per million man-hours worked (N)
1965	80.2	40,100	24	6.0	0.30
1966	75.0	37,500	29	7.7	0.39
1967	82.5	41,250	21	5.1	0.25
1968	85.0	42,500	30	7.1	0.35
1969	66.9	33,450	22	6.6	0.33
1970	86.5	43,250	24	5.5	0.28
1971	82.6	41,300	22	5.3	0.27
1972	71.4	35,700	14	3.9	0.20
1973	66.8	33,400	11	3.3	0.16
1974	69.6	34,800	16	4.6	0.23
Ten-year totals	766.5	383,250	213	5.6	0.28
1975	69.5	34,750	9	2.6	0.13

NOTE: The data include the types of operations listed in Table 1

a From monthly work sheets of Mines Accident Prevention Association of Ontario (excluding prospectors)

b The number of man-years at risk is estimated by dividing millions of man-hours by 2000

c From records of Mines Engineering Branch, for fatalities occurring in metal and non-metal operations, as defined in Table 1

OVER-ALL INJURY EXPERIENCE IN ONTARIO MINES

Fatalities

The over-all fatality record of the metal and non-metal sector of the industry as studied by the Commission is tabulated in Table 27 for the decade 1965–74 and plotted in Figure 10. The decade has seen a significant decrease in the frequency of fatalities, by 45 per cent (on the regression line), which is not wholly accounted for by the changes during this period in the distribution of man-hours worked between underground, open pit, reduction plants, and shops and surface workplaces. As shown in Tables 27 and 28, there has been a significant reduction, from 0.40 to 0.30, in the proportion of the work force employed underground, where the fatality risk of mine workers will be shown to be significantly higher than the risk for the total population. Further, as measured in tons of ore hoisted per man-hour of labour based on all employees, productivity in the metal mines

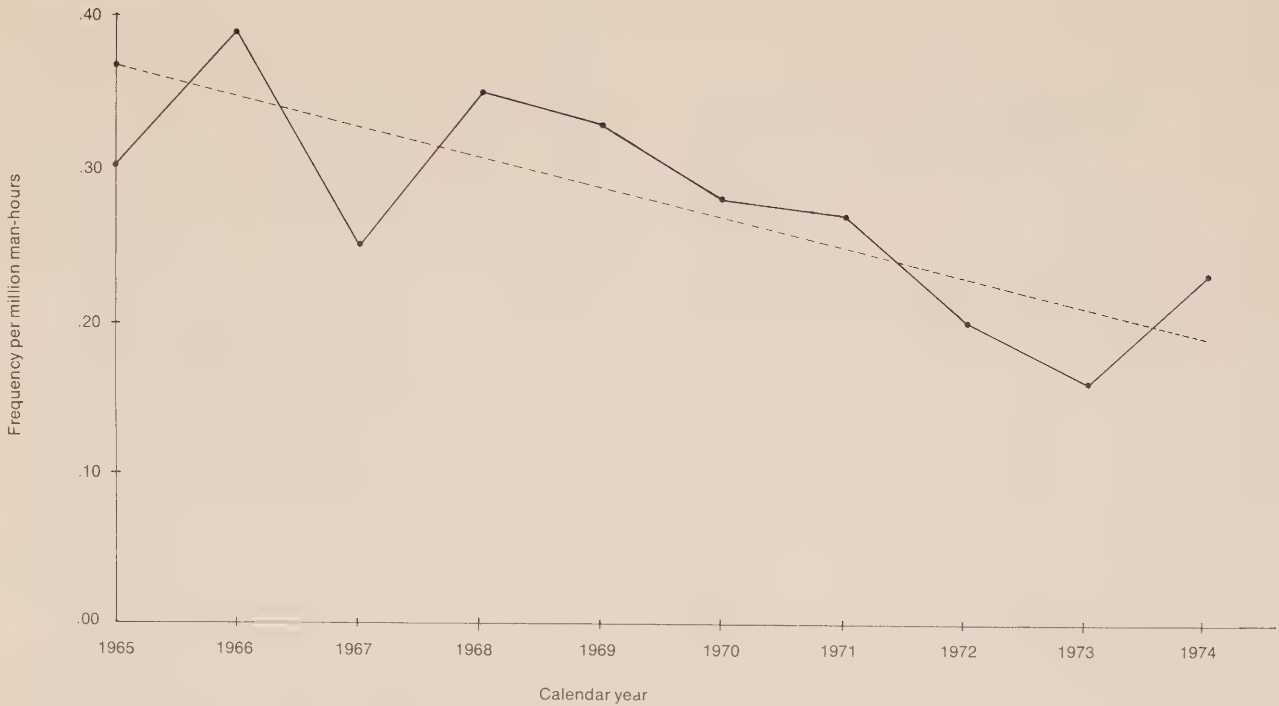


FIGURE 10 Fatality frequency in metal and non-metal mines 1965–74 with fitted regression line (Source: Table 27).

TABLE 28

Comparative fatality rates for underground mine workers in Ontario and Sweden

Calendar year	Man-hours worked (millions)		Fatalities per million man-hours (N)	
	Ontario	Sweden	Ontario	Sweden
1965	32.5	10.9	0.43	0.55
1966	29.6	10.4	0.68	1.15
1967	30.5	9.8	0.39	0.51
1968	30.2	9.8	0.60	1.12
1969	23.1	9.6	0.48	0.94
1970	28.6	8.9	0.60	0.67
1971	26.7	9.1	0.49	1.09
1972	22.4	8.8	0.44	0.56
1973	22.0	8.9	0.32	0.55
1974	21.0	9.0	0.70	0.33

SOURCE: Ontario: Mines Accident Prevention Association of Ontario, *Annual Reports 1966–1975*; Sweden: Svenska Gruvföreningen, *Yrkesskadestatistik vid Svenska Malmgruvor År 1974*, Uppsala, 1975, Figure 7 and other related data

has increased over the decade 1965–74 by an average of about 35 per cent. These changes in employment and productivity reflect in part advances in mechanization and in part changes in the level of operations, for example a notable decline in the gold group.

To place the Ontario experience in perspective, comparisons have been sought with other Canadian and foreign mineral industries. To compare fatality rates between mining industries is reasonable when there are comparable distributions of man-hours worked by types of workplace in mines similarly distributed between metal and non-metal types. Tables 1 and 2 provide representative structural data for Ontario mines. In Figure 11 the fatality rates for the metal and non-metal mines of British Columbia, Manitoba, Ontario, and Quebec are plotted for a ten-year period ending in 1974. These graphs show that experience in four major mining provinces has been comparable in recent years, with Ontario experience comparing favourably. The number of man-hours worked in British Columbia mines is about 25 per cent of that in Ontario, in Manitoba about 20 per cent, and in Quebec about 60 per cent.

Table 28 provides a comparison between Swedish fatality experience and Ontario fatality experience in the underground category, which reflects

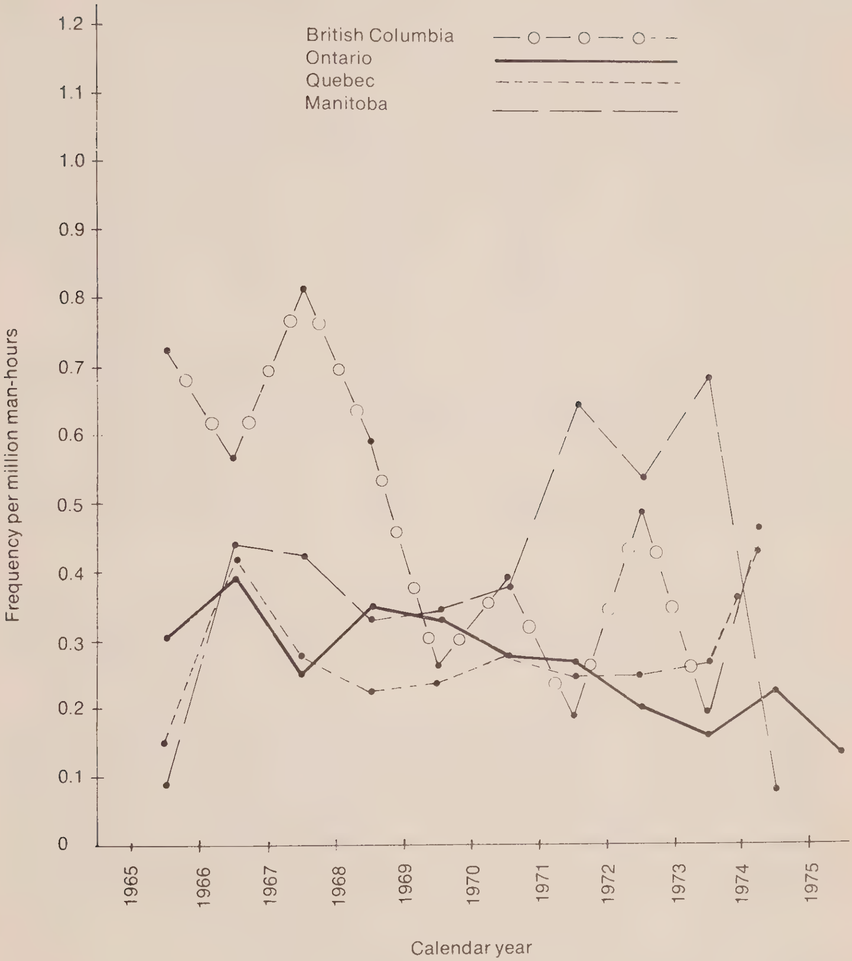


FIGURE 11 Comparative fatality frequencies of selected provincial metal and non-metal mining companies (Source: British Columbia, Ministry of Mines and Petroleum Resources; Quebec, Department of Natural Resources; Ontario, Table 28; Mines Accident Prevention Association of Manitoba, *Annual Reports*, Winnipeg, 1968, 1970, 1974).

TABLE 29

Non-fatal compensable injuries in metal and non-metal mining companies in Ontario 1970–5

Calendar year	Man-hours worked[a] (millions)	Man-years at risk[b] (N)	Injuries[c] (N)	Injuries per 100 man-years at risk (N)	Injuries per million man-hours worked (N)
1970	86.5	43,250	3,575	8.2	41.3
1971	82.6	41,300	3,318	8.0	40.1
1972	71.4	35,750	2,909	8.1	40.7
1973	66.8	33,400	3,220	9.6	48.2
1974	69.6	34,800	3,747	10.8	53.7
Five-year totals	376.9	188,500	16,789	8.9	44.5
1975	69.5	34,750	4,246	12.2	61.0

NOTE: The data include the types of operations listed in Table 1.
a From monthly work sheets of Mines Accident Prevention Association of Ontario (excluding prospectors)
b The number of persons at risk are estimated by dividing the man-hours worked by 2000
c From annual reports of Mines Accident Prevention Association of Ontario (excluding prospectors)

the highest rates.[6] Over the decade, Ontario compares favourably to Sweden, although the many small mines in the Swedish industry give it a different structure.

The foregoing data, as well as reviews of US and other sources where the basis for comparison is less clear,[7] led the Commission to conclude that fatality experience in the metal and non-metal sectors of the Ontario mining industry compares favourably with that in other jurisdictions, though not notably so. Ontario mining fatalities will be compared with those in other sectors of Ontario industry subsequently when the distribution of fatalities among the basic classes of workplace is examined.

Non-fatal compensable injuries

Non-fatal compensable injuries cover an immense range of human consequences, from a lacerated finger to a serious burn to broken limbs. Degrees of disability range from temporary partial to permanent partial disability. Whereas the over-all fatality experience in Ontario mines has been improving, the frequency of non-fatal injuries has been rising, as indicated in Table

FIGURE 12 Non-fatal compensable injuries at metal and non-metal mines 1970–5 (Source: Table 29. The data were obtained from MAPAO monthly work sheets.)

29.[8] These data, plotted in Figure 12, show that a significant rise in the number of injuries per million man-hours occurred in the years 1973 and 1974 and has continued in 1975. Subsequent analysis of industry experience by metal sector for the five-year period 1970–4 will show that the increase has come largely in nickel mining and is in contrast with favourable fatality experience in that sector.

The difficulties of making fair comparisons of fatalities between different jurisdictions have been noted. The problem of comparing experience with non-fatal compensable injuries is much greater because of the ill-defined nature of a compensable injury in different social situations under different legislation. The Commission is not confident enough of the equivalence of data to offer quantitative statistical comparisons. However, it has examined non-fatal injury statistics for the underground employees of US and Swedish metal and non-metal mines.[9] These data show that the

Ontario experience has been superior to, and is now comparable with, that in the USA and Sweden.

Comparative analysis underscores the prevalence of generic risks of fatal and non-fatal injuries in metal and non-metal mines. If the record of injuries is to be improved, it is important to understand how they are distributed on the macro scale of metal group and class of workplace and on the micro human scale of factors such as age, experience, shift, and working alone. These structural reviews will be undertaken first on the macro scale and then on the micro scale, both for fatalities and for non-fatal compensable injuries.

FATALITIES AND THE MACRO STRUCTURE OF THE INDUSTRY

Using data provided to the Commission by the companies operating throughout 1974, the detailed fatality experience of the different metal groups in the industry for the five-year period 1970–4 has been examined. The essential data are presented in Table 30. The relative scale of each metal group is suggested by the 1974 employment figures for total operations, underground, open pit, reduction plants, and shops and surface, as given in columns 1, 3, 5, 7, and 9. Within a given type of operation there is significant variation in fatality frequencies between different metal groups, as shown in columns 2, 4, 6, 8, and 10. For the industry as a whole the risks of fatality in the various operations vary by a factor of about ten, as shown in Table 31. Reduction plants and shops and surface units have much lower risks than underground operations, as would be expected. Open-pit operations are distinctly less hazardous than underground operations. Within the underground segment of operations, as in others, there is a remarkable range of variation in fatality experience among the metal groups. A test for correlation with the scale of operations in the underground segment, shown in Table 32 reveals that fatality frequency is distinctly higher in small operations than in large ones. This fact deserves careful examination both by the companies conducting the smaller operations and by the Mines Inspection Authority. The Commission therefore recommends:

That the Mines Inspection Branch base its patterns of audits in part on studies of the relative risks involved in different segments of mining operations and on the related man-years at risk.

While the industry, through the work of the Mines Accident Prevention

TABLE 30

Fatalities by metal group and class of workplace, ranked by increasing fatality frequency for total operations

	Total operations[a]		Underground		Open pit		Reduction plants[d]		Shops and surface	
Metal group	Employees[b] (1)	Frequency[c] (2)	Employees (3)	Frequency (4)	Employees (5)	Frequency (6)	Employees (7)	Frequency (8)	Employees (9)	Frequency (10)
Diamond drillers	429	0.000	76	0.000					353	0.000
Iron	3,715	0.057	309	0.408	811	0.000	902	0.000	1,693	0.061
Nickel	22,946	0.162	11,178	0.308	136	0.000	8,297	0.035	3,335	0.094
Miscellaneous industrials[e]	930	0.230	288	0.389	72	0.000	265	0.000	305	0.363
Copper	3,145	0.233	732	0.478	176	1.239	483	0.000	1,754	0.067
Uranium	1,632	0.389	854	0.638			198	0.495	580	0.000
Miscellaneous metals[f]	282	0.399			5	0.000	187	0.528	90	0.000
Gold	3,396	0.419	1,960	0.711			377	0.000	1,059	0.000
Shaft sinkers	825	0.731	565	1.005			2	0.000	258	0.000
Silver	147	1.395	78	2.859			21	0.000	48	0.000
All groups	37,447	0.217	16,040	0.446	1,200	0.160	10,732	0.045	9,475	0.066

NOTE: For details by company see Table D.5. Data supplied to Commission by companies operating throughout 1974

a All company operations, including the sectors designated

b Number of employees in the year 1974

c Fatal injuries per million man-hours averaged over the five years 1970-4

d Including concentrators, smelters, metallurgical plants

e Asbestos, nepheline syenite, talc, salt, silica

f Magnesium

TABLE 31

Average fatality frequency per million man-hours for all mining companies

Segment of operation	Fatalities per million man-hours		
Reduction plants	0.045		
Shops and surface	0.066		
Open pit	0.160	All operations average	0.217
Underground	0.446		

SOURCE: Table 30. Frequencies are for the five-year period 1970–4

TABLE 32

Fatality frequencies by scale of operations underground

Scale of operation indicated by number of employees	Fatalities per million man-hours
0–200	0.944
201–1000	0.411
1000+	0.312
Over-all frequency	0.446

SOURCE: Table D.5. Frequencies are for the five-year period 1970–4

Association, is aware of the variability of fatality experience, the Commission has found no evidence that research is undertaken to probe the origins of the observed patterns of risk. The Mines Inspection Branch has a responsibility to the workers, the industry, and the public to do so and to report on its findings.[10] It is therefore recommended:

That the Occupational Health and Safety Branch publish biennially a critical review of factors that influence risks of accident and injury at workplaces in the mines and mineral plants.

Sampling methods as used in this report are one way of exploring particular facets of concern.

Interest was expressed during the Commission hearings about the risks of fatality in the mines relative to those in other sectors of industry. Table

TABLE 33

Comparative fatality frequencies for sectors of Ontario industry

Sector	Fatalities per million man-hours[a]
Manufacturing[b]	0.033
Mining[c] – reduction plant operations	0.045
Mining – shops and surface operations	0.066
Construction[d]	0.148
Mining – open pit operations	0.160
Mining – all operations	0.217
Mining – underground operations	0.446
Logging, sawmilling, and veneer milling[e]	0.786

a Average for five years 1970–4
b Provided by the Industrial Accident Prevention Association. Companies represented include a wide spectrum of activities from retailing to the production and fabrication of textiles, steel, chemicals, automobiles, food, etc.
c Based on data from companies operating in 1974
d Provided by the Construction Safety Association of Ontario
e Based on data provided by the Forest Products Accident Prevention Association

33 provides comparative data for mines, logging, construction, and manufacturing, which show that risks in different segments of mining operations are interspersed with those in manufacturing, construction, and logging. Within mining, underground operations stand out as exceptionally risky, and it is here that the work of accident prevention continues to deserve special attention. The following analysis of the human impact of fatalities in terms of factors such as age, experience, shift, and working alone will underscore this point.

THE HUMAN IMPACT OF FATAL INJURIES

The following analysis is based on a study of 213 fatalities occurring in the decade 1965–74. The fatality reports of the Mines Engineering Branch were used as the primary source of data. The Commission obtained from INCO Ltd, which represents in its operations approximately half of the employment in the industry, estimates of the distribution of workers by years of experience and by working shift. The estimated distribution of workers by age was obtained from the Canadian Census (1971).[11]

TABLE 34

Distribution of fatalities by category of personnel

Personnel	Proportion of employees[a]	Observed proportion of fatalities[b]	
Unskilled/semi-skilled	0.35–0.65	0.81	0.88
Group leader		0.07	
Skilled trades	0.45–0.15		0.05
Supervision	0.10	0.06	0.07
Management		0.01	
Engineering/technical	0.05		Nil
Clerical	0.05		Nil

a Table D.6
b Total number of fatalities: 213 for the decade 1965–74

The relation of fatalities to age, experience, working shift, and working alone will be examined by comparing observed fatalities to those that would be expected if the occurrence of fatalities were independent of each of these factors. It will be shown that an hypothesis of independence is sustained for age, but not for experience, time of working shift, or working alone. It will be inferred that the training of workers and the role of first-line supervision are important issues for the industry.[12]

Table 34 shows how fatalities are distributed by category of personnel and reveals that 0.88 of all fatalities occur among unskilled persons, semi-skilled persons, and group leaders, while the proportion of such persons in the work force ranges from 0.35 to 0.65. First-line supervisors experience risks comparable to those expected, while the skilled trades and other categories experience much lower risks. These data confirm that the major source of fatalities is in work undertaken by unskilled and semi-skilled persons for whom training and supervision are crucial issues.

Table 35 provides statistical evidence that fatalities are not occurring with significantly higher frequency at one age than at another. This result has been interpreted as arising from the fact that younger persons assign a high subjective risk to work situations in mines and that this subjectively assigned risk declines with age as experience grows.[13] In contrast with this result, the data in Table 36 show that the observed number of fatalities for persons with less than five years of experience at the mine of last employment is substantially greater than the number expected on the basis that experience is not a factor. Thus 0.62 of all fatalities occurred among persons with less than five years of experience, while only 0.26 of all

TABLE 35

Age as a factor in fatalities

Age	Observed fatalities[a] (N)	Expected fatalities[b] (N)	Difference[c] (Observed–Expected)
<20	5	8.3	−3.3
20–24	40	38.1	1.9
25–29	24	28.1	−4.1
30–34	23	24.9	−1.9
35–39	27	23.6	3.4
40–44	25	23.0	2.0
45–49	29	20.9	8.1
50–54	11	18.7	−7.7
55–59	18	15.5	2.5
>60	11	11.7	−0.7
Total	213	213	0.00

a For the decade 1965–75

b The expected number is based on the age distribution given in Table D.6 on the hypothesis that fatalities are independent of age

c For this table, $\chi^2_{(9)} = 9.6$, which is consistent with the null hypothesis ($0.25 < P < 0.50$).

SOURCE: Commission study

fatalities would be expected in this group if experience were not a factor. There is clearly increased risk of fatal injury for persons with less than five years' experience at the company of last employment. The data of Table 37 show that this risk is further elevated for unskilled and semi-skilled persons. Whereas 0.67 of all fatalities among persons classified as unskilled and semi-skilled occur among those with less than five years' experience in the company of last employment, only 0.38 of all fatalities among other categories of personnel occur among persons with less than five years' experience.

The combination of data in Tables 36 and 37 gives clear indication that unskilled and semi-skilled persons with less than five years' experience at the company of last employment are at much higher risk of suffering a fatal injury than are other workers. These risks are generic to mining, and Ontario experience is not inferior to that in comparable jurisdictions. Nevertheless, this evidence raises the question whether or not training for, and supervision of, underground work in the mines is adequate in the light of what society is now prepared to accept as risks of work. The following

TABLE 36

Fatalities related to years of experience at the company of last employment

Years of experience (where known)	Observed fatalities[a]		Expected fatalities[b]		Difference[c] (Observed–Expected) (N)
	Number	Proportion	Number	Proportion	
<1	54	0.28	22.8	0.12	31.2
1–5	65	0.34	27.1	0.14	37.9
>5	73	0.38	142.1	0.74	−69.1
Total	192	1.00	192.0	1.00	00.0

a For the five-year period 1970–4
b Based on the reference population defined in Table D.6
c The null hypothesis that fatalities are not related to experience was tested. For this table, $\chi^2_{(2)} = 129.3$, which is significant at the 0.005 level, thus providing strong evidence against the null hypothesis.
SOURCE: Commission study

TABLE 37

Fatalities by category of personnel and years of experience 1965–74

Personnel	Observed proportion with indicated years of experience with company of last employment				
	<1	1–5	≲5	>5	All
Unskilled/semi-skilled	0.32	0.35	0.67	0.33	1.0
Other	0.12	0.26	0.38	0.62	1.0

SOURCE: Commission study

data support the view that there are identifiable circumstances on which to work to reduce fatality frequencies.

The distribution of fatalities with respect to shift worked, shown in Table 38, provides statistically significant evidence that the risk is greater on the night shift from 11:00 PM to 7:00 AM. A specific examination of the distribution of fatalities by age and shift has shown that 0.30 of all fatalities among persons in the age group 20 to 24 years occur on the eleven-to-seven shift, whereas the expected proportion of fatalities in this age group on this shift is 0.13, under the assumption that the distribution of ages on the three

TABLE 38

Fatalities by shift worked 1965–74

Hours of shift	Observed fatalities (N)	Expected fatalities[a] (N)	Difference[b] (Observed–Expected)
7–3	118	125.46	−7.46
3–11	57	60.49	−3.49
11–7	38	27.05	10.95
Total	213	213.00	00.00

a Based on reference population data given in Table D.6, the null hypothesis that fatalities are independent of shift was tested

b For this table, $\chi^2_{(2)} = 5.08$, which is significant at the 0.10 level, thus providing some evidence against the null hypothesis

SOURCE: Commission study

TABLE 39

Fatalities by shift 1965–74: proportion with less than five years of experience with company of last employment

Shift	Proportion	Expected
7–3	0.60	0.26
3–11	0.54	0.26
11–7	0.81	0.26

NOTE: Expected based on the reference population data given in Table D.6 and assuming the distribution of experience among workers on all shifts is the same

shifts follows that in Table D.6. Thus, younger persons working on the night shift are indicated to be at substantially excess risk. This evidence is not inconsistent with the earlier observation that fatalities as a whole are distributed over all age groups in proportion to the population in each age group. The above risk may be combined with that related to experience, shown in Table 39, where it is shown that the proportion of all fatalities occurring on the night shift among persons with less than five years' experience at the company of last employment is 0.81, whereas the expected proportion is 0.26.[14] Again, these data raise the questions of training and supervision, which are further emphasized by the following observations on fatalities while working alone.

During the hearings of the Commission the representatives of labour

TABLE 40

Fatalities by shift occurring among persons working alone 1965–74

Hours of Shift	Working alone Number	Working alone Proportion by shift	Not alone Number	Not alone Proportion by shift	Total
7–3	27	0.23	91	0.77	118
3–11	10	0.18	47	0.82	57
11–7	11	0.29	27	0.71	38
All shifts	48	0.23	165	0.77	213

TABLE 41

Fatalities by shift among persons working alone 1965–74

Hours of shift	Proportion working alone	Proportion not working alone	Expected proportions
7–3	0.56	0.55	0.59
3–11	0.21	0.28	0.28
11–7	0.23	0.17	0.13
All shifts	1.00	1.00	1.00

NOTE: The expected proportion is taken to be the proportion of workers on a given shift as listed in Table D.6, the assumption being that this distribution applies to the subpopulations working alone and not working alone.

unions time and again expressed concern that working alone underground in mines entails exceptional risks that should be reduced by improved supervision. Table 40 shows the number and proportion of the working-alone fatalities occurring by shift; the proportion that working-alone fatalities are of all fatalities is 0.23. Table 41 shows that a significantly larger proportion than expected of working-alone fatalities occur on the night shift, but not on the other shifts. This would suggest that the supervision of work on the night shift may be at issue. The data of Tables 42 and 43 indicate that for both those working alone and those not working alone fatalities occur significantly more often than expected for persons having less than one year's and less than five years' experience at the company of last employment.[15]

TABLE 42

Fatalities by experience and working alone 1965–74

	Fatalities by years of experience (N)			
Conditions of work	Less than 1 year	1 to 5 years	More than 5 years	Total
Alone	16	14	17	47
Not alone	35	51	56	145
Total	54	65	73	192
Total as proportion	0.28	0.34	0.38	1.00

NOTE: Years of experience with mine of last employment, where known

TABLE 43

Fatalities: proportion of total by experience and working alone 1965–74

Years experience with mine of last employment	Working alone	Not working alone	Expected proportion
Less than 1	0.34	0.26	0.12
1 to 5	0.30	0.35	0.14
More than 5	0.36	0.38	0.74
Total	1.00	1.00	1.00

NOTE: See note to Table 41

In the light of the foregoing analysis, the Commission concludes that the basis for training and supervision of the persons classified as unskilled and semi-skilled and in particular those employed in underground work merits review by the industry as a whole. The current basis for, and status of, training in the mines will be discussed and recommendations made after completing this review of fatalities and non-fatal compensable injuries.

It has been noted that injuries arise as particular consequences of accidents, the roots of which in turn depend on training, supervision, work standards, personal behaviour, and many other factors. The particular kinds of accidents associated with fatalities are intrinsic to mining and appear to be relatively invariant between jurisdictions. Table 44 provides some insight into the generic situations in which fatalities occur in Ontario mining operations in the metal and non-metal mines.

TABLE 44

Fatalities by kind of accident 1965–74

Type of accident	Proportion of all fatalities[a]	Proportion of fatalities associated with a given kind of accident		
		Less than 5 years experience[b]	Less than 1 year experience[c]	Working alone[d]
Fall of ground	0.249	0.55	0.24	0.17
Fall of person	0.216	0.64	0.39	0.33
Haulage	0.202	0.74	0.37	0.28
Fall of object	0.131	0.73	0.23	0.07
Run of muck	0.066	0.50	0.14	0.07
Explosives	0.052	0.64	0.27	0.18
Drowning	0.023			
Burns	0.023			
Suffocation	0.023			
Electrocution	0.010			
Fatigue	0.005			
Total	1.000			

a The total number is 213 for the decade 1965–74

b Proportion occurring among persons having less than five years of experience at the company of last employment. The expected proportion is 0.26 on the assumption that the subpopulation of workers with less than five years of experience encounter each accident situation with the same frequency. See Table D.6

c Proportion occurring among persons having less than 1 year of experience at the company of last employment. The expected proportion is 0.12

d The proportion of workers working alone is not known.

NON-FATAL COMPENSABLE INJURIES AND THE MACRO STRUCTURE OF THE INDUSTRY

The frequencies of occurrence of non-fatal compensable injuries in a given segment of operations vary among the metal groups by a factor of about five, as shown in Table 45 in columns 2, 4, 6, 8, and 10. This degree of variability within a common type of operation indicates that a substantial reduction in frequency of injuries could be achieved if the record of the best group was emulated by others. For the industry as a whole, the frequencies vary between types of operations by a factor of about four, as summarized in Table 46. This degree of variation is lower than that for fatalities shown in Table 31. Although the highest risk for all types of injuries is in under-

TABLE 45

Non-fatal compensable injuries by metal group and class of workplace

	Total operations[b]		Underground		Open pit		Reduction plants[e]		Shops and surface	
Metal group	Employees[c] (1)	Frequency[d] (rank) (2)	Employees (3)	Frequency (4)	Employees (5)	Frequency (6)	Employees (7)	Frequency (8)	Employees (9)	Frequency (10)
1 Diamond drillers	429	82.7 (9)	76	108.6					353	73.6
2 Iron	3,715	22.7 (3)	309	27.8	811	27.9	902	30.3	1,693	15.0
3 Nickel	22,946	54.8 (7)	11,178	80.0	136	36.1	8,297	44.0	3,335	15.1
4 Miscellaneous industrials[f]	930	33.2 (5)	288	49.0	72	24.8	265	29.9	305	31.6
5 Copper	3,145	14.4 (1)	732	30.9	176	18.6	483	17.3	1,754	6.1
6 Uranium	1,632	20.7 (2)	854	33.5			198	11.4	580	6.1
7 Miscellaneous metals[g]	282	109.2 (10)			5	98.5	187	122.0	90	65.9
8 Gold	3,396	28.2 (4)	1,960	39.2			377	15.6	1,059	9.7
9 Shaft sinkers	825	39.7 (6)	565	44.7			2	9.0	258	27.4
10 Silver	147	55.1 (8)	78	85.8			21	22.0	48	25.5
All groups	37,447	44.9	16,040	66.9	1,200	28.4	10,732	41.2	9,475	16.5

NOTE: For details by company see Table D.7. Data supplied to Commission by companies operating throughout 1974

a Groups ordered by increasing fatality frequency, as shown in Table 30

b All company operations, including the sectors designated

c Number of employees in the year 1974

d Non-fatal compensable injuries per million man-hours averaged over the five years 1970–4. The rank number is in order of increasing frequency and should be contrasted with the order of the metal groups as per note *a*.

e Including concentrators, smelters, and metallurgical plants

f Asbestos, nepheline syenite, talc, salt, silica

g Magnesium

TABLE 46

Non-fatal compensable injuries: average frequency for all mining companies 1970–4

Segment of operations	Frequency per million man-hours		
Shops and surface	16.5	Average all operations	44.9
Open pit	28.4		
Reduction plants	41.2		
Underground	66.9		

NOTE: Compare with Table 31 for fatality frequencies
SOURCE: Table 45

ground operations, the ordering of risks for fatalities and non-fatal injuries differs in the other segments of mining operations.

A distinctive fact emerging from Table 45, in which metal groups are ranked by order of increasing over-all fatality frequency, is that the rank order for over-all non-fatal compensable frequency is quite different. It might be expected that a metal group's experience with non-fatal compensable injuries would be correlated to its experience with fatal injuries, but the five-year sample of data studied by the Commission reveals no significant direct correlation.

In Figure 12 it was noted that the frequency of non-fatal compensable injuries has risen significantly since 1972. Figure 13 shows that this increase has been occurring primarily in underground operations and reduction plants. A further division of reduction plants into concentrators and other plants including smelters has shown that the increase has been occurring primarily in smelters and related reduction plants rather than in concentrators. Further, the recent increase in frequency is concentrated in large operations located in the nickel group. Analysis conducted over the industry as a whole with the intent of testing the null hypothesis that non-fatal injury frequency is unrelated to scale of operations as measured by the numbers of employees led to no significant evidence to the contrary. However, there are distinctly anomalous individual operations, which may be identified in Table D.7.

Part of the total increase in the frequency of non-fatal compensable injuries is understood to result from a decision by certain companies to cease offering light-duty employment to workers who are temporarily partially disabled, so that the associated injuries formerly classed as light-duty now are classified as compensable. There is also some likelihood that

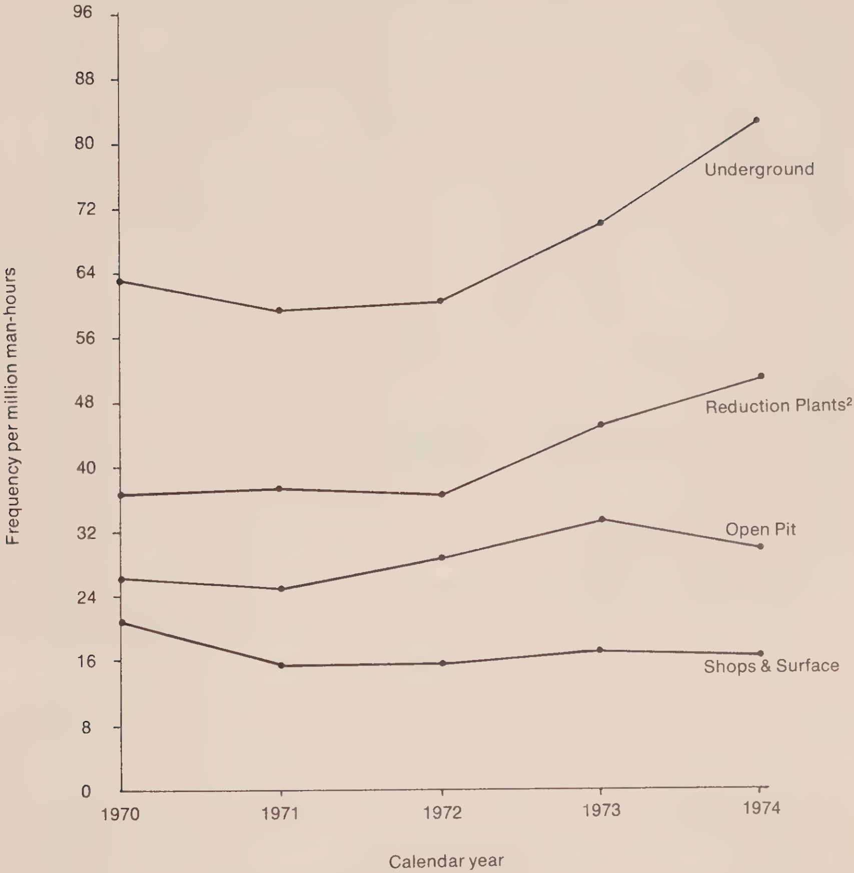


FIGURE 13 Non-fatal injury experience 1970–4, by segment of operations (Note: Figure 12 provides data for all operations together; Reduction plants include concentrators, smelters, and other metallurgical plants. Source: Company data provided to the Commission).

the circumstances of injury under which a worker, in consultation with an attending physician, elects to remain absent for one or more days following the date of an accident are becoming more diverse. Nevertheless there is ground for concern about the rising rate of non-fatal compensable injuries, especially in the light of the following analysis of their relation to age, experience and shift.

TABLE 47

Non-fatal compensable injuries by age

Age (where known)	Observed injuries[a] (N)	Expected injuries[b] (N)	Difference[c] (Observed–Expected)
<20	119	53.94	65.06
20–4	329	247.56	86.44
25–9	231	182.56	48.44
30–4	195	161.81	33.19
35–9	114	153.51	−39.51
40–4	134	149.36	−15.36
45–9	118	135.53	−17.53
50–4	65	121.70	−56.70
55–9	52	100.96	−48.96
60+	26	76.06	−50.06
Total	1,383	1,383.00	00.00

a From records of Workmen's Compensation Board October 1975 through January 1976 for Class 5

b Based on reference population data given in Table D.6

c These data were tested for the null hypothesis that age has no effect on the frequency of accidents. For these data, $\chi^2_{(9)} = 226.06$, which is significant at the 0.005 level thus providing strong evidence against the null hypothesis

SOURCE: Commission study

THE HUMAN IMPACT OF NON-FATAL COMPENSABLE INJURIES

To obtain some insight into the effects of age, experience, and shift on the incidence of non-fatal compensable injuries the Commission analysed in detail the records of the Workmen's Compensation Board for a sample of 1388 non-fatal compensable injuries occurring in Class 5 for the period October 1975 through January 1976 for which the records were complete or nearly complete. Injuries to prospectors were excluded. All of the following results are based on this sample and on the expected distributions of persons by age, shift, and experience given in Table D.6.

Whereas there is evidence, given in Table 35, that fatal injuries are not age-dependent (although they are strongly experience-dependent), the evidence of Table 47 is that non-fatal compensable injuries are age-dependent. There is an excess of injuries among persons under thirty years of age, and the relative excess is greatest in the youngest age groups.

With respect to the relation of non-fatal injuries to working experience at

TABLE 48

Non-fatal compensable injuries by experience at the company of last employment

Years of experience (where known)	Observed injuries[a]		Expected injuries[b]		Difference[c] (Observed–Expected) (N)
	Number	Proportion	Number	Proportion	
less than 1	306	0.23	161.13	0.12	144.87
1 to 5	398	0.29	190.91	0.14	207.09
more than 5	650	0.48	1,001.96	0.74	−351.96
Total	1,354	1.00	1,354.00	1.00	000.00

a Records of Workmen's Compensation Board, October 1975 through January 1976, for Class 5, with prospectors excluded

b Based on reference population defined in Table D.6

c These data were tested for the null hypothesis that experience has no effect on frequency of accidents. For these data, $\chi^2_{(2)} = 478.53$, which is significant at the 0.005 level, thus providing strong evidence against the null hypothesis.

SOURCE: Commission study

TABLE 49

Non-fatal compensable injuries by age and experience at company of last employment

Age	Proportion of all fatalities				
	<1	1–5	≲5	>5	All experience
<30	0.36	0.44	0.80	0.20	1.00
≳30	0.10	0.15	0.25	0.75	1.00

SOURCE: Commission study

the company of last employment, Table 48 shows that there is a significant excess of observed over expected accidents for persons with less than five years' experience. It will be noted that for persons with less than one year's and less than five years' experience, the observed proportion of injuries exceeds the expected proportion by a factor of two. A similar excess of fatal injuries has been noted in Table 36.

The interrelation of non-fatal injuries with both age and experience is shown in Table 49. Whereas 80 per cent of all injuries to persons less than thirty years of age occur among persons with less than five years' experience, only 25 per cent of all injuries to persons over thirty occur in this experience group. Such data add strong evidence that non-fatal injuries, in

TABLE 50

Non-fatal compensable injuries by shift

Shift	Observed injuries[b] Number	Observed injuries[b] Proportion	Expected injuries[b] Number	Expected injuries[b] Proportion	Difference[c] (Observed–Expected) (N)
7–3	725	0.52	817.53	0.59	−92.53
3–11	509	0.37	394.19	0.28	114.81
11–7	154	0.11	176.28	0.13	−22.28
Total	1,388	1.00	1,388.00	1.00	00.00

a Sample of Workmen's Compensation Board records for October 1975 through January 1976

b Based on reference population defined in Table D.6

c The data were tested for the null hypothesis that non-fatal injuries are independent of shift. For this table, $\chi^2_{(2)} = 46.73$, and is significant at the 0.005 level, giving strong evidence against the null hypothesis.

SOURCE: Commission study

addition to fatal ones, are incident to an exceptional degree upon younger, inexperienced persons.

As a final test the Commission examined in a manner similar to that of the foregoing tables the relation of non-fatal compensable injuries to the shift of work. On each shift the proportion of the total injuries occurring in persons having less than five years' experience at the company of last employment is about twice that expected under the assumption that injuries are independent of experience. Further, there is statistical evidence that the total number of injuries occurring on different shifts is not independent of the shift. The relevant data are given in Table 50, where an excess of injuries is apparent on the three-to-eleven o'clock shift. A separate test of the proportion of the total number of non-fatal injuries to persons under thirty years occurring on each of the shifts revealed that a larger than expected proportion occurred on the three-to-eleven shift (0.42 observed versus 0.28 expected). It will be recalled from Table 36 that fatal injuries are in excess on the eleven-to-seven shift. This combination of evidence that injuries may be in excess on other than the main working shift must add to concern for training and supervision.

The generic accident situations in which non-fatal injuries occur are given by proportion in Table D.8 and the characteristic seats of injury on the body are given in the same table. The consequences of non-fatal injuries vary in a wide spectrum from temporary partial disability of minor

duration to permanent partial disability not only of suffering but also of lessened capacity to earn wages. Fatalities are in a tragic sense self-classifying. The important issue is that all of the parties that need to know be advised of injuries in a manner that facilitates the use of the information for the well-being of workers. Forms designed to facilitate the administration of compensation may lack information that is crucial for accident research. The Mining Act already requires the reporting of all fatal and non-fatal compensable accidents and in addition certain dangerous occurrences.[16] These arrangements are commendable and have been the source of key information for use by the Commission. What is disturbing is how difficult it is to render the masses of data pertinent to basic questions in accident studies. To improve the basis for audit and research, the Commission recommends:

That the Occupational Health and Safety Authority, in consultation with the Workmen's Compensation Board, industry, and labour, review the procedures for the reporting of injuries and accidents with a view to establishing links to occupational records and thereby facilitating accident research by sample methods.

SUMMARY OF THE RECORD OF INJURIES, FATAL AND NON-FATAL

The over-all Ontario fatality record of the metal and non-metal mines has been improving and is comparable with, if not superior to, that in other Canadian and foreign jurisdictions. Within the Ontario industry, small companies as a group have distinctly poorer records than large companies as a group. The generic risks in the different segments of operations of the industry as a whole differ by a factor of ten, with underground operations exhibiting much the highest risk.

In contrast with the fatality record, the over-all record of non-fatal compensable injuries, while apparently comparable in level with that in similar jurisdictions, has been deteriorating, mainly in large operations. Redefinition in some companies of light-duty injuries as compensable injuries and a socially motivated liberalization of the circumstances in which absence from work for at least a day following an injury is recommended by the attending physician, expected by the worker and his union, and accepted by the company are, in the Commission's view, contributing to the rise. The rectification of statistical records should cause only a temporary disturbance in the trend of reported injuries. Unexpectedly,

there is little correlation between fatality experience and non-fatal injury experience. For example, in INCO Ltd, whose employment is about half that of the industry, the non-fatal injury frequency has been rising significantly while fatalities are below average for the industry.

There is clear statistical evidence, arising from both fatal and non-fatal injuries for the whole industry, that the generic risks of mining are falling in disturbingly excess proportion on young persons of limited experience and skill. However, it should be recognized as inevitable that excess risks will be experienced by younger and less experienced persons; what is at issue is the extent to which this excess can be reduced. The potential years of life lost and the lost years of full enjoyment of normal physical capability arising from accidental injuries far exceed those from industrial disease. If the frequency of accidents is to be reduced significantly, the question of training and supervision for the worker is central, as is the question how in a given company anomalous departures from accepted standards of technical operations and human performance are detected and corrected. Every party bears some responsibility.

ACCIDENTS AND THE PERFORMANCE OF WORK WITHIN A MINING OPERATION

The following sketch of the responsibility-system for the performance of work is intended to generate a framework within which to identify roles and to derive corresponding recommendations.

The legal framework governing the operation of mines is set out in Part IX and Sections 621, 624, 625, and 626 of Part XI of the Mining Act of Ontario. In a practical sense these parts of the Act may be viewed as a form of contract between the public, represented by government, and a mine owner, whereby the management of a mine is assigned certain generic duties and specific responsibilities, together with wide power to make decisions required to fulfil these responsibilities. The conduct of management in meeting these requirements under the Act is currently audited by the staff of mine inspectors of the Mines Engineering Branch in the Ministry of Natural Resources.

Beyond the legal framework of the Mining Act, the employee has the legitimate right, under the principle of natural justice, to appraise the conditions under which he works and to express his views of their adequacy. Thus, the voluntary nature of a worker's decision to accept employment does not imply acceptance of the adequacy of working conditions

as found or the diminution of the obligation of the owner to fulfil the duties and responsibilities as defined in the Act.

The requirements governing the operation of mines under the Mining Act place the onus on management to ensure that 1/ the conditions of work meet well-defined standards and 2/ the tools and equipment are suitable for the work and maintained in proper condition. The Commission would add a third obligation which is not made as clear as it should be in the Act, namely, to ensure that 3/ the employees are adequately prepared through training and experience to engage safely in productive work under normal conditions and to recognize and report anomalous conditions of work.

Once the foregoing obligations are met by management the onus is on worker and supervisor to ensure that 1/ standard work procedures are followed, 2/ standard conditions of work are maintained, and 3/ tools, equipment and processes are properly used.

It is a premise of this study that properly performed work will preclude accidents. In mining the conditions under which work is performed are subject to continual change both physically at the workplace and generically in technology and methods. The proper performance of work must therefore depend not only on the effectiveness of a system of work administration through which human effort is co-ordinated but also on the effectiveness of the means whereby this system monitors its own performance and adapts to changing conditions. The Commission believes that the fundamental basis for accident prevention lies in the ability of each person to perform his duties in a self-determined manner within clearly defined boundaries of authority and responsibility. In this context, and from the evidence of briefs, hearings, expert opinions, and intensive visits to mining operations, the Commission concludes that there is a need for greater clarity and openness with respect to such simple questions as 1/ who is responsible for detecting departures from standards of work performance, 2/ who carries the responsibility to make the decision whether or not action is to be taken, and 3/ who is then responsible for seeing that the anomaly is corrected.

It was observed that anomalous conditions may arise from plant and process design and layout, from the care and maintenance of tools and equipment, from work practices in the use of equipment and in the operation of processes, from the manner of performing tasks, and from personal and group behaviour. Instances of anomalous conditions or departures from standards have been adduced in all of the previous chapters, and there is no reason to believe that any one type of anomaly is dominant as the root

of accidents. If there is argument that the dominant cause lies in unsafe acts, this report provides strong indications that the extent of training of both workers and supervisors and the effectiveness of management and supervision are also at issue. Anomalous conditions pertain to production, to health, and to safety and are inextricably related.

The question of the prerogative of managerial responsibility in matters of health and safety was debated at length in the Commission hearings. In the Mining Act the authority to define policies that govern the response to anomalous conditions and the power to provide physical and human resources to correct them rests in the hands of management. This same base of managerial authority would exist in any form of revised industrial democracy involving worker participation in management.[17] The locus of ultimate accountability has been well stated by the United Steelworkers of America as follows: 'the employer must accept the full legal and moral responsibility to provide a safe and healthy workplace, protective equipment, safety and health training, and safe work procedures.'[18]

It is critically important that the managerial system for the performance of work be effective. Table 51 was prepared as a model to demonstrate how the duties of all persons in an organization can be interrelated to achieve integration of the responsibilities essential to the effective performance of work. This table will be referred to as 'the internal responsibility-system for the performance of work.'

Let us examine the roles within the internal responsibility-system depicted in Table 51. For each of the levels of occupation extending from workman to president the elements of responsibility related to the job are identified succinctly in vertical columns. The elements of the rows define the tasks to be performed by the collective hierarchy in organizing the performance of work. When these organizational tasks are correctly integrated there is a unity of responsibilities. The progressive change in the character of the elements from the purposes of organization at the top management level to the operational detail at the workplace reflects the devolution of duties for each occupational level in the organization. Crucial to the capacity of the system to recognize and respond to departures from standard conditions is its own performance in defining the basis for standard conditions at every level of the organization through 1/ providing detailed job descriptions, 2/ specifying the personal prerequisites necessary to carry out the work characteristic of the job, and 3/ the definition of the responsibilities entailed in the job. The responsibilities associated with the performance of the duties as defined in the columns of Table 51 must be

adequately understood and prepared for if the person is to be able to perform the role effectively and to be held accountable for the identification and correction of the departures from standard conditions. It is management's underlying responsibility to see that this internal responsibility-system is effectively in place and in particular that there is open understanding among all parties of their duties and responsibilities in the performance of work. In particular it is essential that the processes of communication at the interfaces between levels of responsibility be well defined and operative. In view of the scale and technology of mining operations, a significant part of the variability of injury experience, both fatal and non-fatal, identified within metal groups can be attributed, the Commision believes, to the degree of effectiveness of internal responsibility-systems.

The responsibility for internal accounting with respect to anomalous conditions is defined in the bottom row of Table 51. The preceding two rows define responsibilities for sustaining standard conditions at the workplace and for facilities and equipment used. The hearings and investigations of the Commission support the view of the labour unions that in some mining operations departures from standard conditions are recognized by workers and first-line supervisors but are not regularly acted upon with reasonable promptitude by the internal responsibility-system. There are at least two consequences of such a situation. The first and most important is that the worker's and supervisor's commitment to the importance of correcting anomalous conditions may be undermined. The second consequence is that the existence of such situations may only be revealed by the external audit system through the attention of mine inspectors and, before detection, may lead to preventable accidents. It is a misuse of the role of mines inspection for any management to rely on this external process of audit as a primary means of detecting departures from standard conditions.

In the complex developmental character of hard rock mining, it is unreasonable to expect unvarying perfection of quality in tools, machines, and working conditions; nor is it reasonable to expect the performance of work to be free of human error and misjudgment. However, there ought to exist, and to be understood by all who need to know, clearly defined and supervised standards of performance including concern for the safety and health of workers. The essence of this understanding is the capacity to recognize and to correct departures from standards even in such simple things as housekeeping. Lax standards become not only accepted standards but expected standards. The Commission therefore recommends:

TABLE 51

Internal responsibility-system for the performance of work

Responsibilities	Occupation level: Workman	1st-line Supervisor	2nd-line supervisor	Superintendent	Manager	President and chief executive officer
Nature of work	Process material	Assign tasks	Schedule work	Interpret objectives Plan operations	Determine objectives	Establish purposes
Responsibility for people	Direct helpers	Instruct and develop workmen	Develop supervisors Allocate workforce	Select and develop supervisors Provide workforce	Select and develop staff	Select manager
Responsibility for work performance	Use knowledge and skill Exercise initiative	Direct work performance within clearly defined job specifications	Specify duties and responsibilities Define authority	Assign duties and responsibilities Delegate authority	Determine functions Delineate spheres of responsibility Delegate authority	Delegate operating authority
Responsibility for direction of work	Carry out work in a manner consistent with approved practices and procedures	Carry out duties in a manner consistent with policies and procedures and philosophy of enterprise	Carry out duties in a manner consistent with policies and procedures and philosophy of enterprise	Interpret policies and procedures in light of business philosophy in administration of business activities	Establish business philosophy Develop operating policies Standardize administrative procedures	Determine business philosophy and procedures
Responsibility for relations with people	Work co-operatively with others	Co-ordinate performance of tasks	Co-ordinate work programme	Co-ordinate supporting services	Conduct the operation of the enterprise in a manner compatible with legislated requirements and social trends	Determine policies to make the purposes of the enterprise compatible with lesgislated requirements and social trends
Responsibility for facilities and equipment	Use facilities, equipment, machine[s] and tools	Provide adequate tools and equipment	Provide adequate services and machines	Make provision for necessary facilities, machines, and equipment	Obtain capital goods	Authorize capital expenditure

Responsibility for conditions of work	Maintain standardized condition	Implement standardized condition	Provide facilities for standardized conditions	Set standards of work performance and working conditions	Determine standards of work performance and working conditions	Determine policies for the operation of the enterprise
Responsibility for accounting	Inspect facilities of workplace, machines, and working conditions Inspect work and report on task accomplishment or reason for not doing so Report on condition of machines, workplace and work environment	Report on work progress and workplace requirements Report anomalous conditions	Report on workforce, workload, and anomalous conditions, and facility requirements	Report on department activity and anomalous conditions	Develop effective audit system Account for the state of enterprise in terms of business viability and security of employment	Account to owners on state and progress of enterprise and to public on discharge of responsibility of trusteeship

That the senior management of each mining operation review the performance of its internal responsibility-system, placing special emphasis on the delineation of 1/ responsibility to detect and to report departures from standard conditions at every level of operations, 2/ location of responsibility for ensuring that identified departures are dealt with, 3/ procedures for committing the resources to correct anomalies, and 4/ procedures for checking the action already taken and still to be taken.

The apparently common view that the great majority of accidents are the direct result of nothing more than unsafe acts or unsafe conditions is, in the Commission's opinion, too restricted a view of the human problem of accidental injuries. Workmen and their supervisors at every level may act unwisely, but they do so within a system for the performance of work whose responsibility it is to set clear and supervised standards of what is expected. Within such a system workers have a clear obligation to perform work by standard procedures, and supervision has the responsibility to see that standard conditions of work, tools, and equipment are maintained. At times, accidents in themselves may distract attention when in fact the responsibility-system for the performance of work deserves to be the focus of concern.

Any internal system of direct responsibility will be imperfect and requires audit, not because of any inherent defect in form but because it is a human organization in which conditions of work and concern for the well-being of persons create grounds for tension. The major element of external auditing currently in use is that of mines inspection under the Mining Act. To this process of inspection the Commission will propose that there be added *worker-auditors* drawn from the ranks of employees and a well-defined role for joint labour-management health and safety committees. Each of these three elements, namely, mines inspection, worker-auditors, and joint health and safety committees play a distinctive role supplementary to and in an important sense external to the basic processes of accountability that are internal to the employee-employer relationships in the system for direct responsibility depicted in Table 51.

External audit can keep the basic internal system alert and responsive, but it cannot substitute for basic internal integrity which rests on the knowledge, training, experience, and commitment of management, supervisor, and worker. All parties are under an obligation to seek to eliminate anomalous conditions organizational, technical, and human. No party can claim that the beam is always in the other's eye.

THE WORKER-AUDITOR

Studies by the Commission indicate that workers as a group with more than five years' experience at a company have a significantly lower frequency of injury than would be expected if experience were not a factor. This fact leads to the conclusion that the knowledge and judgment of this group, as individuals, has a major influence on their abilities to perform their tasks safely at the workplace. While each worker can contribute personally on matters concerning the performance of his specific work through the internal system of direct responsibility discussed in relation to Table 51, there is no established means by which workers can assess conditions of work as a whole, and through which the insight derived from their collective knowledge and experience can be utilized to assist in preventing accidents in mines.

In the hearings before the Commission the labour unions argued for the extension of the mining inspectorate to include a significant fraction of experienced workers in addition to the professional engineers who currently constitute the core of the inspection staff. The Ministry of Natural Resources in its brief proposed that workers should have the option to select and employ worker-inspectors.

The Commission visited the United Kingdom and Sweden, where it investigated the worker-oriented inspection systems cited in the hearings. By statute, mines in the United Kingdom have workmen's inspectors and mines in Sweden have safety delegates whose responsibilities are comparable but not identical.[19] In the United Kingdom, workmen's inspectors are appointed and employed by the labour unions, where such exist. In Sweden the safety delegates are appointed by the labour unions, where such exist, and are paid by the company while performing their duties. Their general function is to monitor and report on conditions of work as these pertain to health and safety.

Believing that provision should be made in Ontario for the review of conditions of work by means of worker-auditors, the Commission recommends:

That statutory provision be made for the appointment in each mine and plant of worker-auditors having the authority and responsibility to examine and report upon conditions of work pertaining to the health and safety of workers at sets of workplaces designated by management in such a way as to encompass all workplaces in underground, open pit, reduction plant, and shop and surface operations.

The basic function of such worker-auditors is to contribute to management and subsequently to the mining inspectorate the judgments of experienced workers on conditions of work pertaining to health and safety in the operations designated for such workers' review. The intended role is an advisory one. Thus in the manner of the workmen's inspectors in the coal mines of the United Kingdom[20] the Commission proposes that the worker-auditor conduct an examination of an area of work, prepare a brief report thereon, and submit this to the mine manager for his written comment. One copy of the completed form containing both the worker-auditor's report and the manager's comments is to be sent to the mining inspectorate and another copy posted for the information of the workers concerned. The intention is to provide management with an additional form of audit of operations while informing the mining inspectorate of the details of the review.

Intending the worker-auditor to be neither the formal agent of the union nor a member of the mines inspectorate, the Commission recommends:

That worker-auditors be given released time with regular wages while performing their duties;

That the Workmen's Compensation Act be amended to make provision for the assessment of the costs of worker-auditors upon employers in Class 5.

The latter recommendation is intended to provide a means of including the costs to employers of worker-auditors within the assessments of the Board and hence of accounting on an industry-wide basis for the costs incident upon employers.

The Commission proposes that worker-auditors devote an appropriate part of one shift per month to the task of reviewing work conditions. If such a system of worker-audit is to function constructively its purpose as part of the whole system for the co-ordination of the performance of work must be clearly understood. The process must be conducted openly, with the worker-auditor scheduling the time of review on a regular basis by arrangement with the manager and being accompanied, as the mining inspector is, by the manager or his designate. The Commission believes it to be important that worker-auditors be accompanied by supervision of the most senior responsibility that is feasible. The worker-auditor is not an instrument of investigation for the collective bargaining unit as such. Through statutory provision he or she undertakes a publicly affirmed obligation to review conditions at designated places of work and to make a report to

management. It is suggested that there be one worker-auditor for every twenty-five workers, more or less,[21] and that the designation of workplaces for review be made by management in consultation with the Joint Health and Safety Committee and the Mines Inspection Branch. Further, the Commission recommends:

That worker-auditors be appointed from among qualified candidates for a period of three years by the collective bargaining unit, where such exists, or be elected by the workers.

To qualify for the role of worker-auditor, a person should 1/ have a minimum of five years of experience in work closely related to one or more of the types of work undertaken at the workplaces designated for audit; 2/ have a minimum of three years' seniority; and 3/ have received adequate instruction arranged and funded by the Occupational Health and Safety Authority in co-operation with the industry and the representatives of the workers.[22] The instructional programme in modular form should deal with issues of health and safety under conditions of work pertinent to mines and under the governing legislation. Worker-auditors should have the right of access to all statutory records for environmental conditions and equipment operation and should understand the function and significance of these and related schemes, codes, and standards for environmental conditions and work practices. He or she should have the right to take, or to request the taking of, environmental measurements at particular places during, or as soon as feasible following, an audit, and to have the results appended to the report.

A system of worker-auditors, by providing a clear basis for experienced workers to contribute to the review of work conditions in a capacity other than in the process of work itself, could, in the Commission's view, strengthen the effectiveness of the internal system of direct responsibility which is at the core of accident prevention. A statutory provision for such audit would be, not an unwarranted interference in the management of enterprise, but rather an affirmation of a public desire that workers have a formal right and the means to review the conditions of the work into which they have entered voluntarily as employees. Such auditing is symbolic not only of the right to review conditions of work with reference to standards but also of the obligation of all parties to adhere to standards. Anomalies affecting health and safety arise on both human and technical grounds. The role of worker-auditor implies the exercise of judgment in recognizing and reporting anomalies of all kinds without engaging in personal identification.

At the Commission hearings the labour unions stated their conviction that a representative of the workers should be present at the investigation of fatalities and serious injuries. Under British law the workmen's inspector has this right. The worker-auditor in whose area an event occurs is the appropriate person to join the mines inspector and others as are now provided for or customary in such events.[23] The Commission therefore recommends:

That there be statutory provision for the appropriate worker-auditor to participate in the investigation of fatal accidents and serious injuries;

That the designated worker-auditor have the privilege of cross-examining witnesses at an inquest into any fatal accident whose circumstances he has participated in investigating.

JOINT LABOUR-MANAGEMENT HEALTH AND SAFETY COMMITTEES

Labour unions have for many years sought the right to be consulted about and to participate in accident prevention at the workplace.[24] Various royal commissions in Ontario have made recommendations for the voluntary or mandatory formation of joint committees of management and employees for purposes of accident prevention.[25] The Workmen's Compensation Act contains provision for the Board to invoke the formation of safety committees for accident prevention in companies with adverse injury experience, although to the Commission's knowledge the Board has not exercised this right.[26]

Joint labour-management health and safety committees currently exist in over 90 per cent of the industry. The Commission's concern is therefore not so much with their formation as with their role. The operational procedures and jurisdiction of existing committees have been negotiated by collective bargaining. The hearings before the Commission have indicated that a number of these committees have become effective instruments for constructive and co-operative consultation on conditions of work related to safety and health. On the other hand, among these committees are also some that meet sporadically with no clear sense of their role and others that meet more often in an atmosphere of frustration, in which the labour members are convinced that undesirable conditions are not being corrected and management members believe that the substance of many complaints is not central to health or safety. In spite of the varied

experiences of such committees in Ontario, the Commission has found no evidence to suggest that at this time 1/ injury experience in Ontario is inferior to that in jurisdictions such as Sweden where union participation is more extensive or 2/ unionized mines have accident records superior to those of non-unionized mines.

If the internal system of direct responsibility depicted in Table 51, checked by mines inspection and examined by worker auditing, is effective in dealing with the bulk of the anomalous conditions that give rise to accidents, a joint labour-management health and safety committee, the Commission believes, can also play an effective role in sustaining the alertness and responsiveness of the whole system. However, if the internal system of direct responsibility functions below some reasonable level of effectiveness it may mean that the capacity of the organization is too limited to make use of the information provided by the committee. Furthermore, without a co-operative will to understand the complex issues of health and safety in the industry it is unlikely that such committees can better the conditions of work. The Commission is strongly convinced that there is emphatically no place for the adversary system of collective bargaining in dealing with matters of health and safety.

The Commission has argued for clear recognition by all parties that the integrity of the internal system of direct responsibility is the key to what actually happens in matters of health and safety. And it has recommended that this system be kept operationally alert by adding to the mines inspection function a provision for the review of conditions of work by worker-auditors. Within this framework the Commission sees an important consultative and advisory role for a joint labour-management health and safety committee that can help to sustain responsiveness to changing conditions. Both labour and the industry, through the Ontario Mining Association, have recommended that the establishment of such committees be mandatory. It is thus recommended:

That there be statutory provision for the establishment of a Joint Labour-Management Health and Safety Committee at each mine and plant;

That the membership of the Committee consist of equal numbers of persons appointed by management and appointed by members of the collective bargaining unit(s), where such exist, and otherwise elected by the workers collectively, subject to the constraint that at least two of the persons selected be worker-auditors;

That the Joint Committee conduct its work as far as feasible during regular

hours of work and that its members receive their regular wages while engaged on committee work;

That the Joint Committee meet regularly at least four times per year and not more often than once monthly.

The variations in scale in the industry make it impracticable to define the optimum size of such a committee or to define the extent to which there can fruitfully be subsidiary committees for segments of operations, for example in smelters, mills, underground, and so on. In one large corporation, INCO Ltd, which has some twenty thousand employees, a new system of one general committee, fifteen area committees, and forty operations' committees has recently been negotiated with the labour union.[27] The question of infrastructure should evolve out of a reaffirmed role for the central committees that now exist in most of the industry, and where mutually agreed practices currently exist the Commission makes no suggestion that these be altered.

FUNCTIONS OF THE CENTRAL JOINT COMMITTEE

So diverse are mining operations that a detailed basis of operations for joint committees should properly be evolved by those engaged in them.[28] However, the Commission believes that certain principles should guide the work of these committees and their subsidiary parts.

In the whole responsibility-system for occupational health and safety, which involves workers, companies, and government agencies, the essential principles of openness and of natural justice have not received adequate expression. This issue is not peculiar to the mining industry. Participation, it has been noted, can be understood in terms of three modes: knowledge (having ready access to information), contributive responsibility (providing individual and collective insight, advice, and judgment), and direct responsibility (making operational decisions). The worker, the supervisor, management, and the mine inspector participate in all three modes. The worker-auditor, as defined above, participates in the first two, and the Commission believes the proper basis for the participation of the joint health and safety committee is also in the first two modes.

The Commission considers the essential role of the joint committee to be that of providing a consultative forum for constructive and critical review of the status of the health and safety of workers as reflected in the performance of the responsibility-system both internal and external to the local

operations. It is a forum of consultation between those with the ability to contribute and those accountable for deciding what is to be done. Someone accountable for making a decision does not impair his decision-making role by consulting those who can contribute to it. Such consultation is indeed very likely to improve both the quality and the acceptability of the decision. The Commission was presented with little evidence that the contributive ability of workers is being tapped extensively by mine management. If it is to be tapped in the deliberations and activities of a joint committee, there must be an atmosphere conducive to the development of a mutual understanding of objectives rather than an atmosphere of confrontation for the purpose of maintaining institutional rights of either party.

Openness, in the sense of establishing a clear basis of knowledge, should encourage co-operation. Workers have not, in the Commission's view, had appropriate access to information concerning environmental conditions at the workplace, to data on the hazards of materials and processes, to reports on injury experience, to reviews of the status of occupational disease, or to schemes, codes, and standards of practice for work and work conditions where such exist. All such data, as well as reports of the worker-auditor and information that management may be expected to table on policy and operations, are relevant to the work of a joint committee.

The Commission suggests that joint committees give attention to policies, system performance, operations, and conditions. These will be discussed in reverse order. While it may be practicable in small-scale operations to discuss all of these elements in a single committee, it will not be so in large mines. The minutes of representative committees currently in operation reveal a tendency to dwell on the disposition of specific anomalies to the exclusion of all else. Workers naturally wish to see particular adverse conditions dealt with, and it is important that a committee should demonstrate its capability at this pragmatic level. However, as the training of persons for such committees improves and as practices of openness become better developed, it is essential for them to reach beyond individual conditions to the generic context in which they occur. Thus, if a joint committee is to undertake tours of operations, which the Commission considers appropriate, such tours should be designed to consider policy in such generic problem areas as the following: 1/ environmental standards, codes, and schemes of practice; 2/ standard work procedures for existing and new methods of work and equipment; 3/ modification and extension of plant; 4/ education and training for health and safety; 5/ the design and use of protective equipment; 6/ the maintenance of tools, equipment, and processes; 7/ the efficient use of ventilation; 8/ the hazards related to

haulage and hoisting; 9/ the use of hazardous chemicals; 10/ housekeeping; and 11/ underground fire procedures.

The internal system for direct responsibility alerted by worker audit and mine inspection has the task of identifying and reporting specific problems. While a tour by a joint committee may unearth such instances its major role should be to understand classes of anomalies. This task may be facilitated by engaging, prior to a tour, in an analysis of the accidents related to the generic problem area under review. It is important that a joint committee have a program for reviewing problems and for advising on policy. Both parties have a responsibility to share in constructing such a programme; simply talking about health and safety is not enough.

The joint committee should have an understanding of how the internal system of direct responsibility is organized to deal with anomalous conditions affecting health and safety and how it functions in introducing changes in methods and technologies. In this regard, if both parties understand the framework in which they meet together, the joint committee can be a constructive vehicle for communicating management intentions and for management in turn to benefit from the insight of workers. The Commission recommends:

That each mining company provide its employees with a written statement outlining its policy for health and safety and the organizational arrangements and responsibilities for giving effect to it.

In the operation of a joint committee it is hoped that opportunity would be taken to benefit on occasion from a visit by an attending physician, an industrial hygienist, and other resource persons who can add perspective to its long-range work. Joint labour-management health and safety committees can be instruments of co-operation for the sustaining of an effective and responsive internal system of direct responsibility and for assisting in the development of policy both within the mining operation and within the whole provincial system for occupational health. There is an opportunity for leadership.

However, if the parties in the committee insist upon emphasizing the dichotomy between unsafe conditions and unsafe acts to the exclusion of a balanced judgment of the risks and benefits in the complex human and technical organism that is a mining operation, both parties will inevitably be disappointed. The greatest bone of contention will probably be whether or not a given condition constitutes an anomaly that may contribute to the occurrence of an incident likely to cause injury. It is essential for differences of opinion on this matter to be frankly stated and recorded, and for

management to indicate when considerations involving feasibility, costs, and so on are determining factors in its response to situations. The mines inspectorate should receive a copy of the minutes of the committee for review, and as necessary the inspector should adjudicate matters referred to him for resolution. In this regard the Commission states its strong conviction that anomalous conditions should as far as possible be dealt with by the persons immediately involved. It would be inexcusable for problems to be presented either to a joint health and safety committee or to the mines inspectorate before the internal system of direct responsibility had been given the opportunity to act. Some aspects of the role of the mining inspectorate in accident prevention will now be reviewed.

THE ROLE OF THE MINES INSPECTORATE IN ACCIDENT PREVENTION

The powers and duties of the mines inspectors as specified in Sections 610 to 612 of the Mining Act were reviewed in chapter 2. The mines inspectorate, as represented by the Mines Engineering Branch of the Ministry of Natural Resources, has interpreted its role in accident prevention as having two distinct parts: 1/ to determine by sample inspection the state of compliance of mining operations with the extensive technical provisions of the Mining Act and to issue written instructions for improving the state of compliance; 2/ to assess the characteristics of existing and proposed mining methods and technology with the intent of establishing codes of practice and subsequent modifications to the Mining Act designed to minimize the risks of their use.

The modus operandi of the inspectorate has been described in the following words:

> We work through periodic inspections. We require mines to provide us with data about their operations. And we receive information from workers and union officials.
>
> When one of our Engineers finds out about a problem or a failure to meet a standard he informs management that they are required to correct it. Normally this order will include a date by which the work must be completed.
>
> Only in cases where the offense is flagrant, or where our written orders are disregarded would charges under the Mining Act normally be laid.
>
> In some cases, it is [not] possible for problems to be corrected or standards met immediately. In those cases, our Engineers work with management to find solutions, and to expedite those solutions.
>
> Our job, in short is to make sure the self-regulatory system is working.[29]

The Commission fully endorses the last statement when the self-

regulatory system is understood to be the system of direct internal responsibility based on the worker, supervisor, and management, as modelled in Table 51. In order to appraise the process of self-regulation in this context it is essential for every mine inspector to develop a sense of the effectiveness of the internal responsibility-system in each mining operation he inspects. The minutes of the joint labour-management health and safety committee and copies of the reports of the worker-auditors should provide some insight on this matter. It has previously been recommended that the allocation of the work of inspection be based in part on the analysis of the relative frequencies of injuries in different mining operations. The mine inspector may need to consult with worker-auditors in the general course of mine inspection. Since it has been recommended that the reports of the worker-auditors be copied to the mine inspector after completion by management, consultation between the mine inspector and the worker-auditor is a natural step.

The mines inspectorate has been staffed by mining, electrical, and mechanical engineers with professional qualifications. The mining engineers inspect primarily underground and open pit operations, while the electrical and mechanical engineers inspect machines, equipment systems, and processes. Unlike mining inspectorates in the United Kingdom and Sweden, the Mines Engineering Branch has inspected metallurgical plants other than mills, that is to say, smelters and refineries. It does not appear to have the expertise in extractive metallurgical processes it will need if it is to continue to have this responsibility.

There are standard inspection forms which enumerate the many technical elements dealt with in the Mining Act. The inspectors generally visit mining operations two to four times a year, spending one or more days during a visit. The actual inspection can at best be a sampling process designed to test management's compliance and to alert it to its responsibilities under the Act. The mines inspectorate in effect acts to monitor, as intensively as its resources permit, the state of mining operations as these pertain to the health and safety of workers. It is not feasible for the inspectorate to police exhaustively the technical detail of the Mining Act. It is the responsibility of the internal responsibility-system continuously to detect and to remove anomalous conditions throughout the operations. The Commission endorses this balance of responsibilities. But the inspectorate has, in the Commission's view, been understaffed and inadequately funded for its role both in accident prevention and in the protection of the health of workers and no doubt these circumstances have affected its morale.

The mines inspectorate should have not only the professional capacity to comprehend the full range of mining operations but also the standing to influence the commitment of senior management to the effectiveness of the internal responsibility-system. The Commission therefore recommends:

That the core of the staff of the Mines Inspection Branch continue to be based on persons of exceptional professional experience in mining, and related fields of engineering, supplemented by special training in occupational health and safety and in the principles of the administration of work.

This same professional capacity is essential to the role of assessing and advising on technological change in mining. In the hearings before the Commission the Mines Engineering Branch was subject to severe criticism from the labour unions on several grounds. Some of these have been dealt with in the preceding chapters. In assessing technological change in mining methods, the Branch seems to have met its responsibilities effectively. Indeed, the work of the Mines Engineering Branch in the development with mines and manufacturers of codes of practice for friction hoists, *in situ* testing of hoist cables, raise climbers, hydraulic backfill, and so on represents in the Commission's view an admirable record.[30] The practice of working closely with mine management on issues of technological change has led to the union allegation of accommodation of interests. While technical expertise is an important ingredient in these matters, so also are practical points of application in mines. The Ministry of Natural Resources has been tardy in establishing policy for consultation between the Mines Engineering Branch and experienced workers. To affirm further the contributive basis for worker input into questions of technological change, the Commission recommends as a matter of principle:

That task groups set up by the Occupational Health and Safety Authority to advise on codes of practice and statutory regulations relating to technological change in mining include representatives of labour.

Through the power conferred by legislation the mines inspectorate must be, and be seen to be, the agent of the public in exercising responsibility to preserve the health and safety of workers involved in mineral development. One manifestation of this public responsibility, namely, a critical annual or biennial report, has been seriously neglected. In the fulfilment of this responsibility it is essential that the mines inspectorate have clear access to and utilize the understanding of both management and workers. To date the contributive capability of workers has been too little called for.

THE TRAINING OF MINERS

For accident prevention by the worker himself, nothing is more important than the extent and quality of training, experience, and supervision. This subject, together with the issue of working alone, will now be considered.

The studies reported in this chapter show that injuries arising from accidents fall disproportionately upon unskilled and semi-skilled personnel with limited experience. If unsafe acts are the major cause of injuries, as asserted by management,[31] it must be asked whether or not workers receive training and supervision of adequate extent and quality. In the light of the fact that fatal and non-fatal compensable injuries cause many times greater loss of potential life years and of life years enjoyed at full physical capability than does industrial disease, no question deserves more careful attention by the mining industry than that of training. In fact the risks in mining are exceptional, and persons do indulge in unsafe acts.

With respect to the preservation of the health of workers it has been pointed out that the Mining Act contains general stipulations calling for the suppression of dust, the removal of noxious gases, and the provision of adequate ventilation. Likewise, with respect to accident prevention, the Act requires that persons engaging in work shall be adequately trained, experienced, qualified, approved, authorized, and so on. The employer possesses the sole authority to determine the qualifications of employees under Section 169 (3), which states that 'subject to the requirements of the Act and except as otherwise provided by the Act, responsibility for the authorization and decision as to the qualifications of employees rests with the employer or his agent.' General conditions for the exercise of this responsibility are specified in a variety of sections of the Act, examples of which are as follows:

Section 169 (14) ... Every Manager shall ensure that no person works without supervision at any machine unless the person, (*a*) has received adequate training and instruction in the operation of the machine and any dangers connected therewith; (*b*) has received adequate supervision by a person having thorough knowledge and experience with the machine; (*c*) is capable of safely operating the machine without supervision.

Section 165 (1) No person under the age of 21 years and no person who has not had adequate experience on a reversing hoist shall be authorized to operate a hoist by which persons are handled in a shaft or winze at a mine.

Section 396 (3) No person, unless he is authorized so to do, shall operate any equipment for controlling the movement of the hoist or interfere with the equipment.[32]

Section 249 (2) No person under the age of 18 years and no person who has not had adequate experience on a crane shall be authorized to operate a crane in a mine or plant.
Section 431 (1) Where electrical equipment is used at a mine or plant, it shall be in the charge of an authorized person who shall be qualified by experience to handle such equipment.
Section 431 (2) Every person operating or having charge of electrical equipment shall have been instructed in his duty and shall be competent to perform the work he is set to do.
Section 431 (3) Repairs, extensions and changes to existing installations shall be made only by qualified persons.
Section 169 (5) It is the duty of every manager, supervisor or other person in charge of workmen and every hoistman, deckman, conveyance attendant or person who handles explosives or blasting agents or who operates, installs or maintains any equipment, machinery or electrical apparatus in or about a mine or plant, to know the requirements of this Part that apply to the work under his charge and direction or in which he is engaged.

In relation to personnel, the Mining Act does not define clearly the meaning of 'adequate experience,' 'qualified,' 'approved,' or 'authorized.' Judgment on these central issues, which is crucial to the health and safety of workers, is the responsibility of the manager. Further, in Section 169 (14) the Act refers to adequacy of training and supervision for the operation of a machine but does not directly require adequacy of training and supervision for the over-all performance of work. The labour unions have been sharply critical of the quality of training provided to underground miners.

On the basis of its hearings and investigations and the evidence provided by the study of accidents, the Commission believes that the level of training of many miners should be improved and that as a matter of principle there should be improved means of verifying that management ensures the adequacy of training and qualification for all new and upgraded employees.

Before the basic issue of training for work is considered, certain important arrangements for training miners to deal with accidents deserve commendation. Fire is one of the terrible hazards of mining. Since 1929, under the provisions of the Mining Act and under the direction of a Mines Rescue Superintendent attached to the Mines Engineering Branch,[33] a system of Mines Rescue Stations has been maintained throughout the province. These stations provide to some miners, who volunteer and are paid regular wages plus a bonus by their companies, expert training and practice in working in simulated fire situations; about six hundred miners and two hundred supervisors currently participate. These mine rescue crews are

organized to converge on a mine where there is a fire.[34] The training has been so standardized that mine rescue crews can work without loss of effectiveness with crews of other companies, in other districts, and at other mines. They compete annually for a trophy and maintain a splendid level of competence and morale. In the past thirty-eight years since the Mine Rescue Stations were set up, only one life has been lost because of fire in an Ontario mine. Many mine companies require their first-line supervisors to hold a St John's Ambulance First Aid Certificate, and in some mines a significant number of workers hold certificates. The Commission strongly commends this programme.

The following discussion of training for work focuses on the novice underground miner, who the Commission study shows, encounters the highest risk of accident, but it applies with like force to other categories of workers. The Commission is concerned with principle, rather than detail, the latter being beyond its competence. The training of employees in mines and plants has been and remains largely an on-the-job proposition whereby new employees are introduced to the work environment and are shown the methods of work by their supervisors and fellow employees. This procedure, while suited to the varied and immediate needs of the company, has resulted in great variation in content and emphasis on training and has led to difficulties in establishing consistent records of evaluation for defining the qualifications of persons ostensibly doing the same kind of work who move about not only within a given mining operation but also within the industry. These problems are not new to industrial training,[35] but they are emphasized by the diversity of mines and of mining methods. Parts of the industry, particularly in Northwestern Ontario, have also been facing severe problems of labour turnover.[36]

The following excerpts from company training procedures for novice miners, the majority of whom have left formal schooling before Grade 9 or 10,[37] illustrate the distinctive types of training.

Short-term induction, followed by training on the job

The procedures of one company are intended to

> provide each new employee with the basic knowledge and skills needed to perform his job safely including the Company's philosophy of safety, good housekeeping, fundamentals of safe work procedures, requirements of the Mining Act, safety equipment and its uses, first aid, reporting of injuries and many others. Basic work methods are demonstrated in the field allowing the new employee to become familiar with his job. At the end of this one-week training period he is required to pass a qualification test before joining the regular work force.[38]

This procedure is designed to introduce a person to a basic job. If and when a worker changes jobs, further training is provided. Training periods are commonly interspersed between periods of experience. The units of training are delivered by a variety of persons to standards determined by those within the company who deliver it.

Phased stages of training a development miner
The procedures of one company are as follows:

Phase I (2 to 4 weeks)
The novice is assigned to the conveyor belt clean-up crew under a full-time supervisor. He is constantly supervised from the time he reports ... In this phase the primary job is conveyor clean-up. However, the crew is moved all over the mine on general clean-up work. During this period of from 2 to 4 weeks, the man becomes acquainted with the underground surroundings, the terminology used on the job, procedures in safety, fire, etc. ... The trainee attends a weekly safety and instruction meeting ...

Phase II (4 to 6 weeks)
At this point he becomes more oriented to the job, as he assists in pipefitting, supply distribution, general housekeeping, and occasionally helps a miner in the stopes. In these ways he obtains an indication of what a miner's job consists of. At Phase II, the trainee is supervised by a production shift-boss. He is more or less on his own, and is given jobs as required on the beat ...

Phase III (8 to 12 weeks)
This is the focal point of the whole program, the beginning for a production miner ... The candidate is put into a school stope with two other trainees, working under the constant and direct supervision of a Training Stope Instructor. Here the trainee is given instruction for a minimum number of hours in the various elements of practical and safe mining ...
A. Work Area Preparation and Maintenance
B. Drilling
C. Use of Explosives and Blasting Accessories
D. Ore Removal
The Director of training reviews the trainee's performance with him once a week ...

Phase IV (2 to 4 weeks) – Advanced Stope
At this point the trainee leaves the instructor. He is on his own with a partner and is put into a stope to practise the skills which have not yet become second nature. The work is lined up by the Training Shift Boss who is around constantly. Here he begins to feel the demands of production, and starts to appreciate what he can do for himself ... When it appears, usually after two to four weeks, that the trainee's safety

performance and his initiative would not adversely affect the incentive earnings of other qualified men, he is given a written test. If he achieves the required marks a certificate is presented to him at one of his safety meetings. He is then transferred to a regular production beat, classified as a general miner and receives a miner's rate. A further period of time will evolve before the trainee-miner can be considered to be an all-around miner.[39]

The significant structural elements here are staged training delivered in a coherent sequence with regular evaluation by a director of training, followed by a form of certification. The content of training remains wholly company-determined.

Modular or block training

This form of training for novice miners was introduced into the mining industry by one company in 1974 and is in use in related forms in other companies.[40] The system for novice miners is carried on in co-operation with the Industrial Training Branch, Ministry of Colleges and Universities, and has been described as follows:

Each job is broken down into its essential tasks or elements of work. By combining these tasks into various combinations, complete job profiles are made up in any pattern or combination required. Each module contains a performance and safety standard. This system of training provides for the accreditation of each employee who has completed a training course in each module or block. Testing is done by a show-and-tell basis and no written exams are required. Accreditation certificates are issued by the Industrial Training Branch, Ministry of Colleges and Universities ...

A new employee ... upon entering the mine is required to go through a Basic Program. This takes 40 man-hours or 1 week's training. After successful completion he is then put into a mine beginner's job or a labourer's job, or he can go straight into the Drill School for a further 2 week's training, of 80 man-hours and receive the further 4 modules of drilling.[41] Upon successful completion of the drilling section, he will then go into the School Stope No. 1 and receive training in a further 10 modules, which takes about 2 weeks, or 80 man-hours. After successful completion of this section he is now qualified to function as a stope driller ... Putting a person through a 1, 2 or 5 week training program does not necessarily mean that he is fully qualified as there is still the factor of experience to be considered.

The distinctive feature of the modular form of training described above is the introduction of standard definitions and descriptions of elements of work which are established as printed standards, maintained in a central registry, and accredited by an agency other than the company itself. This

system therefore provides a basis for standardization of training and of transferability and recognition of training. The Commission believes that the modular system of training for miners and other workers in the mines and plants should be vigorously developed through tripartite co-operation of the industry, labour, and government and therefore recommends:

That the industry, government, and labour give high priority to the development, standardization, and accreditation of modular training and qualification for workers in mines and plants.

A tripartite committee convened by the Ministry of Colleges and Universities began meeting in September 1975 to study the development of modular training.

In the development of the elements of the modular system the expertise of the colleges of applied arts and technology and the universities should be provided as necessary. There is a singular opportunity here for the post-secondary educational system to serve the many workers who by the nature of their work have not needed formal access to the system but deserve the full benefit of its interpretive knowledge on all matters related to the interplay of technology, human behaviour, health, and safety at work.

There are certain structural principles that the Commission commends for consideration in the development of modular training pertaining to the health and safety of miners. The following subjects are considered relevant for training by modules: 1/ standards for personal protective equipment and for conditions at the workplace, including statutory regulations relating to health and safety; 2/ practical technical knowledge and skill in the selection, use and maintenance of tools, machines, processes, and practices; 3/ standard work procedures; 4/ the organization of work generally; 5/ the supervision of work; 6/ the system for the performance of work in a particular mine or plant.

A simple model of the functional elements for training and qualification is shown in Table 52. In this sketch the responsibility of the first-line supervisor spans all elements. In the design of sequences of modules to implement the scheme in Table 52 for particular types of jobs it is recommended that four levels of work responsibility be clearly distinguished. These are 1/ working dependently as a helper under direction of an experienced worker, 2/ working as a qualified miner independently and possibly alone, 3/ working as a crew leader with one helper, and 4/ working as a lead hand directing team work. Further, it is recommended that accreditation of

TABLE 52

Classification of workers by stages of training and qualification

	Dependent worker, stages of training		Independent worker, stages of qualification		
	General labour trainee	Helper	Stage 1: Improver	Stage 2: Crew leader	Stage 3: Lead hand
Status	Works under constant supervision or guidance	Works with, and under direction of, experienced co-worker	Works independently with no direct responsibility for others	Works independently and directs the work of helper	Works independently directing the work of two or more helpers or co-workers
Function	To work as instructed	To work as directed	To work independently and make personal decisions on performance of work	To make decisions for self and helper on conduct of assignment	To make decisions for self and team on conduct of assignment
Purpose	To learn and to use basic work methods and procedures	To gain experience and broaden knowledge of related work methods and procedures	To improve skill and perform specified tasks	To perform a range of job-related tasks	To organize work, to assign tasks, and to direct performance of work

the modular system of industrial training be at two levels, namely, training and minimum qualification, through satisfactory completion of one or more modules of training and accumulation of a specified minimum of satisfactory experience in the use of a module. Thus, the Commission envisages a certificate of completion of one module, or of groups of modules, being endorsed at the completion of training and further endorsed after the accumulation of the qualifying extent of satisfactory experience. The worker must be assured that his personal record is meticulously maintained and available to him as required and on separation.

The viability of an extended modular system of training in which there is some basis for quality control by an accrediting agency external to the company will depend on the co-operation of the parties in defining subsets, or sets of core modules, whose significance in contributing to the qualification of a worker can be agreed upon and widely recognized.[42] Qualification objectives should be developed for key classes of jobs. Guideline sequences of modules expressing these objectives should be prepared by the industry and made known to the Occupational Health and Safety Authority. It is important that the mining inspectorate be able, as a matter of principle, to check the qualifications of persons according to the Mining Act. The accreditation of modules by the outside agency is to promote uniformity of training as a primary factor in the qualification of workers. The process of accreditation must not pre-empt the responsibility of the manager under the Mining Act to ensure that workers are adequately qualified.

The labour unions have argued for a statutory provision for certification of a journeyman miner, such as was recently adopted in Manitoba,[43] whereas the industry has opposed statutory certification.[44] It is beyond the terms of reference of the Commission to consider this matter. But the Commission observes that the improvement of the training of mine workers can and must be continued while this basic provincial question of a policy for industrial training is being resolved. All parties agree that an improved system for the training and personal development of workers is a desirable and feasible objective, and the Commission believes that our society will rightly demand it.

THE ROLE OF THE FIRST-LINE SUPERVISOR

No position is more important to safe production than that of the first-line supervisor – the shift boss or foreman. It is a position of stress and responsibility. The underground shift boss, having received from his

supervisors a work plan for current operations, then has the responsibility to 1/ assign workers to work places; 2/ ensure that necessary services, materials, tools, and machines are available; 3/ instruct upon and supervise the conduct of the work; 4/ ensure that departures from standard conditions are corrected; 5/ prepare time records of the workers; 6/ report on operations; and 7/ assist in developing the capabilities of the persons he supervises. The men under his supervision may be scattered over a large area of one or more levels of the mine. In the course of a shift he will visit each crew at least once to discuss with them procedures and problems, to check on conditions of work, and to review some element of safety at work. In assigning men to workplaces he must recognize pertinent provisions of any collective bargaining agreement. He must appraise the conditions of the ground not only out of concern for safe working but also to advise on the adjustment in incentive contracts for time allowances for scaling, drilling, and so on. He must keep in touch with the ventilation department to ensure that local conditions of ventilation are standard, and he must respond to and investigate accidents.

From the foregoing sketch of his duties it is apparent that the first-line supervisor should 1/ understand the organization and administration of the internal responsibility system for co-ordinating the performance of work of which he is a significant part; 2/ understand the work standards and conditions applicable in his area, without necessarily being expert therein; 3/ understand the hazards to health and safety associated with anomalous working conditions; 4/ be able to make a decision that action be taken; 5/ have the authority to ensure that a decision is carried out; 6/ have the freedom to exercise his authority and hence to be free from unwarranted encroachment on, or intervention in, his role; and 7/ have capacity for leadership.

These elements suggest on the one hand the nature of various modules or blocks of knowledge in which a first-line supervisor should be trained, and on the other hand certain critical aspects of his relationships both with workers and with senior supervision. The Commission strongly believes that the competence, morale, and leadership of the first-line supervisor is crucial to the effectiveness of the internal system of direct responsibility for the performance of work which is the foundation for accident prevention. Leadership throughout this internal system is the force that binds it together. It takes form through the delegation of responsibility, the conferring of complementary authority, and the exercise of these elements.

Through its hearings and investigations the Commission is concerned to

have noted that the morale of shift bosses may be undermined by senior supervisors, both through their unresponsiveness to reported anomalous conditions and through downgrading his authority by their intervening in his area of responsibility. Such indications lead the Commission to place singular emphasis on the need in mining operations for clear communication and understanding within the internal system of direct responsibility for work.

THE TRAINING OF SUPERVISORS

Not all the companies submitting briefs to the Commission addressed the question of training of supervisors. Of those that did comment on the subject, attention was directed to the expansion of the working knowledge of the supervisor in specific aspects of the company operations, personnel policies, identification of hazards, development of personal skills, and so forth. Reference was also made to the use of programs offered by the MAPAO and directed chiefly to the fundamentals of environmental controls and of accident prevention. Some companies incorporate courses developed by the American Management Association dealing with principles of work administration, supervisory techniques, and personal skills.

From the Commission's limited study of supervisory training it is apparent that there are great differences between companies in what is being done. Supervisors questioned on the subject indicated both strongly favourable and unfavourable feelings about the effectiveness of their training. This situation means that supervisory training may suffer from such limitations as the following: 1/ lack of relevance to the organization structure as it is understood by the first-line supervision; 2/ inconsistency with attitudes of management and senior supervision as these appear to the first-line supervisor; 3/ obscurity in the manner or means whereby the chain of responsibilities is integrated; 4/ incompatibility between the theory of supervision and experience in practice.

A programme of supervisory development will have much more meaning if it emanates from the top of the organization in clear statements of policy and philosophy for the conduct of operations, and if the training aspects include active involvement by management and senior supervision as the sources of insight into the functions of occupations and the duties of office, such as those outlined above and in Table 51. In this way the objectives of management would be identified and the desired means for attainment would be made evident in explanations of procedure by senior management and in demonstration by example.

WORKING ALONE

In the hearings of the Commission the labour unions expressed concern about the risks undertaken by persons working alone while relatively remote from co-workers in underground operations. There are situations for which the Mining Act requires that the work be conducted by more than one person. These include blasting and work in enclosed tanks in plants.[45] Working and undertaking risks while alone is a common human experience. Farming and logging are two activities in which many persons work alone. The latter has higher fatality risks than underground mining. After studying the evidence available for our mines the Commission cannot recommend that working alone be proscribed. However it is concerned to ensure that management's inherent responsibility to assign properly qualified workers to work alone is meticulously exercised.

Under current standards of supervision, persons working alone may be visited not more than once every four hours, or once per shift other than at the start of the shift. The record of fatalities for the past decade among persons working alone has been reviewed in Tables 40–4. There is sample evidence in Table 43 that a disproportionate number of all fatalities, namely, those working alone and not alone, occur among persons with less than one year of experience in the company of last employment. The Commission therefore recommends:

That persons assigned to work alone be required to have specified qualifications for independent work at the job to which they are assigned.

By 'specified qualifications for independent work' is meant the second category in the system outlined in Table 52 with significant practice in performing safely the work assigned.

A further question is the extent of supervision and of communication intended to confirm the well-being of the miner. It is recommended:

That on all shifts persons working alone be visited at the place of work at least three times (other than at the start of a shift) by a first-line supervisor;

but

That such visits may be reduced to once per shift (other than at the start of a shift) if 1/ work conditions are standard; and 2/ means of communication are provided and a record of use thereof is kept so that the person working

alone reports his status to a point of supervision or to a designated fellow worker not less often than once every two hours.

Further, the Commission recommends:

That where the location of work is sufficiently remote to warrant the use of technical means of communication and where no illumination other than that of the miner's cap lamp is normally available, an auxiliary source of illumination powered by means other than the miner's lamp battery be provided at the workplace;

That all fatalities and serious injuries to persons working alone underground be the subject of biennial review by the Occupational Health and Safety Branch.

THE RIGHT TO REFUSE TO WORK UNDER UNSAFE CONDITIONS

The labour unions have contended that a mine worker should have the right to refuse to perform work or to operate a machine when he believes the situation or the machine to be unsafe (see n. 18). The word 'unsafe' applies both to conditions associated with accidents and to environmental conditions affecting health.

This report has emphasized the importance of the capacity of a well-audited internal responsibility-system to detect and to correct departures from standards in machines, in work procedures, and in conditions at the workplace, including environmental conditions. Workers and supervisors have a right and a need to know what these standards are, to be trained to recognize significant departures from standards, and, in so far as their responsibilities extend, to deal with them. It is unconscionable to suppose that workers are required to perform work in situations that their supervisors suspect to be unsafe beyond the unpredictable characteristics of mines, machines, and men. The first responsibility of all persons in performing work is to maintain prescribed standards, since it is within this framework that the bounds of regularly encountered risks are controlled. The worker-auditor, the joint health and safety committee, and the mining inspectorate exist to keep this system of responsibility alert and responsive to departures from standards for the performance of work.

Within this internal system the one situation requiring further study is

that of the individual worker or small group of workers active at a workplace where an exceptional risk or unsafe condition is deemed to have arisen at a particular time during a shift, so that it is believed that work cannot safely be performed in a standard manner. The exceptional risk or unsafe condition may be related to the workplace and its environment or to the machines and devices being used. With respect to machines and devices the Mining Act makes the following specific provisions under Sections 169 (15) and (16):

(15) No manager, supervisor or his agent who has reasonable cause to believe that any machine or device in or about a mine or plant is unsafe or in contravention of this Act shall cause or permit it to be used or operated.
(16) No person who has reasonable cause to believe that any machine or device, which has been assigned to him for use in or about a mine or plant, is unsafe or in contravention of this Act shall use the machine or device until he has: (*a*) reported the defect to his supervisor; and (*b*) obtained specific instructions in writing from his supervisor to use or operate the machine or device.

The need for Section 169 (16) stems from the possibility that a machine or device may be unsafe or in contravention of the Mining Act without the knowledge of management and supervision. The Commission understands that, in application, Section 169 (16) may lead to the following outcomes: 1/ the judgment of the supervisor is in support of the worker's belief and the machine or device is withdrawn from service for repair; 2/ the judgment of the supervisor is contrary to that of the worker, the worker is given verbal reassurance or written instructions to use or operate the machine or device, and he proceeds with one of these forms of reassurance to operate the machine or device; 3/ the judgment of the supervisor is contrary to that of the worker first assigned to the machine or device, but a second worker is assigned to and operates the machine or device and no written instructions are given to either the first worker or the second. The Commission, concerned that under outcome (3) a record of the worker's judgment is not recorded, and having argued for improved means by which the judgment of workers can more effectively contribute to the operation of the internal responsibility-system, therefore recommends a clarification:

That Section 169(16) (b) be amended (and be included in a revised Act, to be recommended) to require the supervisor to make a written report which: 1/ states the nature of the condition of the machine or device which in the worker's belief renders it unsafe for use; 2/ gives the supervisor's comments at the time; and 3/ gives the supervisor's confirmation or otherwise that Section 169(15) is, in the supervisor's view, satisfied;

That the worker who refers a machine or device to his supervisor under Section 169 (16) (b) as amended sign and receive a copy of the supervisor's report.

The Commission emphasizes that the invoking of Section 169 (16) (b) as amended should be expected to be a relatively infrequent event, but the judgments of the worker and of the supervisor, both deemed to be acting responsibly, should be reported to the internal responsibility-system as information to improve its operations in maintaining machines and devices.

The provisions of Sections 169 (15) and (16) apply only to machines and devices. There remains the situation in which some other condition at the workplace is deemed by a worker to prevent the performance of work in a standard manner without the undertaking of unreasonable risk.

Since the inherent risks in underground mining are higher than in any other sector of mining operations, it will be the context of this discussion. The shift boss assigns work at the beginning of a shift and subsequently visits the men at least once per shift. It is the practice in underground mining for all work to stop and consultation to take place about the current conditions of work whenever the shift boss visits the workplace. If, when the shift boss is not available, a miner judges that conditions, for example of ground, have become such that the work assigned cannot be performed in a standard manner without undertaking unreasonable risks, it is expected that he and his immediate co-workers will await or seek the further guidance of supervision and if necessary while awaiting guidance withdraw from any place judged to present imminent danger to life or limb. Just as it is possible for there to be differences in judgment between a worker and his supervisor about the condition of a particular machine or device, it is clearly possible for such differences of judgment to exist with respect to the risks of performing work under the conditions at a particular workplace, even after the normal processes of consultation intrinsic to mining have taken place. Nevertheless, it is the responsibility of the shift boss to assign work and to decide if the conditions for that work meet standards for its performance. In a more open and better audited internal responsibility system the exercise of the responsibility will continue to be a heavy one. There is, in the Commission's view, no substitute for the exercise of this responsibility supported by first class training and experience.

The Commission would expect a substantive difference in judgment between a worker and his shift boss about a condition of work to be a relatively infrequent event, but since both parties would be deemed to be acting responsibly, the work should be visited and judged by a senior level of supervision. It is therefore recommended:

That where a worker, after due consultation with his immediate supervisor, believes that the work then assigned cannot be performed by standard procedures without encountering personal risks deemed by him to be unreasonable, there be a statutory requirement that the work situation be examined and judged by a member of senior supervision in the presence of a worker-auditor acting as an observer and that a report of the circumstances be made to the mines inspectorate by the manager.

The situations in which the foregoing recommendation would be invoked would by their nature be ones of great tension between the workman and his supervisor. The worker has a right in natural justice to be assured that a well-considered disagreement in judgment between himself and his immediate supervisor about the risks of work can be fairly examined and that he will suffer no discrimination for having stood by his convictions.

1 Jean Surrey, *An Annotated Bibliography for Industrial Accident Research and Related Fields*, Labour Safety Council of Ontario, Toronto: Ministry of Labour, April 1969; International Labour Office, *Human Factors and Safety*, Geneva: International Occupational Safety and Health Information Centre, CIS No. 15, 1967; International Labour Office, *Encyclopaedia of Occupational Health and Safety*, 2 vols, Geneva, 1971; W.T. Singleton, *Introduction to Ergonomics*, Geneva: World Health Organization, 1972; D.F. Jones, *Human Factors – Occupational Safety*, Toronto: Labour Safety Council of Ontario, Ministry of Labour, 1973

2 J.A. Fletcher and H.M. Douglas, *Total Environmental Control*, Toronto, 1970

3 Workmen's Compensation Act, Ontario, Sections 39, 40, 41

4 Transcript, 1068, 1187–8, 1762

5 Transcript, 1125–6

6 The available Swedish data on the mining industry as a whole does not include all reduction plants and therefore cannot be compared to the over-all Ontario figures.

7 The following sample of US data for underground operations of metal and non-metal mines was obtained:

Calendar year	Millions of man-hours worked	Number of fatalities per million man-hours
1973	65.0	0.75
1974	70.3	0.68

These figures are about twice Ontario figures for the same years. Source: MESA Safety Reviews, *Metal and Non-metal Mine Injuries Fourth Quarter and Summary 1974*, Washington DC: US Department of the Interior, Mining Enforcement Safety Administration, March 1975

Over-all comparative data for mining fatalities in Japan, Canada, Sweden, and the USA were tabled before the Commission by the United Steel Workers of America (Exhibit 99) and modified by the insertion of Ontario data by the Ontario Mining Association (Exhibit 125). The pattern of these data is consistent with the more specific review undertaken by the Commission.

8 The definition of a compensable accident was changed by the Workmen's Compensation Board in 1969 from a three-day to a one-day basis. Thus, in 1969 and subsequently, a non-fatal accident became compensable when a worker was absent for one or more days, rather than three or more days following the day of the accident. The precise definition has been given in the text.

9 For US data on disabling injuries see MESA Safety Reviews, *Metal and Non-metal Mine Injuries*. A disabling injury is defined as one such that the worker does not return to his regular place of work on the day following the accident leading to the injury. For Swedish data see Svenska Gruvföreningen, *Yrkesskadestatistik Vid Svenska Malmgruvor År 1974*, Meddelande nr 137, Volym 9, Uppsala, 1975. The definition of a non-fatal injury as used by the Swedish Mining Association is formally the same as that used by the Workmen's Compensation Board in Ontario.

10 The annual reports of Her Majesty's chief inspector of mines and quarries in the United Kingdom provide an example of what is done in other jurisdictions.

11 See Table D.5 for reference distributions used in comparing observed with expected numbers of fatalities.

12 The analysis to be given for the industry as a whole is based on samples as defined and is subject to sampling error. Inferences are drawn only where there is clear statistical significance.

13 Transcript, 1071–2

14 It is possible that, because older persons with greater seniority prefer not to work at night, younger persons are being assigned to the eleven-to-seven shift in numbers larger than would be expected on the assumption that the age distribution in the reference population is independent of the shift worked.

15 There are other interesting features of data related to working alone. Thus, while Table 35 indicates that the frequency of all fatalities is independent of age, the following data indicate that the fraction that occur when working alone may be age-dependent. It is not possible, however, with the data available to the Commission to determine appropriate expected proportions.

Age	Proportion of fatalities at a given age occurring while working alone
<20	0.20
20–24	0.25
25–29	0.17
30–34	0.17
35–39	0.15
40–44	0.16
45–49	0.33
50–54	0.18
55–59	0.38
>60	0.36

16 Mining Act, Part IX, Sections 605, 606

17 Paul Malles, *The Institutions of Industrial Relations in Continental Europe*, Ottawa: Information Canada, 1973

18 United Steelworkers of America, *Summary of Proceedings, Canadian Policy Conference*, Vancouver, May 1974, 18 (Exhibit 84)

19 United Kingdom, *Mines and Quarries Act*, Section 123 (1)–(4) as extended by the *Health and Safety at Work etc. Act 1974*, HMSO, London, 1975, Sections 2 (4), 2 (5); Sweden, *Workers' Protection Act and Workers' Protection Ordinance*, Ministry of Labour, Stockholm, September 1974, Section 40

20 Form 216, 'Report of Inspection on Behalf of Workmen,' Under the Mines and Quarries Act, HMSO, London

21 The number twenty-five is intended as a guide and may be adjusted as circumstances suggest. A simple calculation will indicate that the direct cost to the company in wages of a

worker-auditor system is about one-quarter of 1 per cent of payroll. The current direct assessment for compensable injuries and industrial disease by the Workmen's Compensation Board on Class 5, the bulk of which is represented by the metal and non-metal mines, is at an average level of 6 per cent of gross payroll. The budget of the Mines Engineering Branch of the Ministry of Natural Resources, which provides mine inspection, currently represents less than 0.5 per cent of gross payroll for Class 5.

22 The Tripartite Committee on Training in Mining set up by the Manpower Training Branch of the Ministry of Colleges and Universities in September 1975 is a suitable vehicle for initiating a task group whose responsibility it would be to devise a training programme for worker-auditors. The Commission proposes that the training programme be funded and administered by the Occupational Health and Safety Authority, whose functions are defined in chapter 6. This task group should have membership from the Occupational Health and Safety Authority, the Mines Inspection Branch, the industry, and labour. The assistance of colleges of applied arts and technology and of the universities should be sought. The programme should be available to persons such as safety stewards designated by labour unions on a fee-paying basis to be agreed on.

23 The Mining Act, Sections 604 and 605

24 A representative review of one major union's experience is given in *A History of Steelworkers' Action for Occupational Health in Ontario Mining*, United Steelworkers of America, District 6, January 1976

25 Mr Justice Roach, *Report of the Royal Commission on the Workmen's Compensation Act*, Toronto, 1950; His Honour Judge P.J. McAndrew, *Report of the Royal Commission on Industrial Safety*, Toronto, 1961; Mr Justice McGillivray, *Report of the Royal Commission in the Matter of the Workmen's Compensation Act*, Toronto, 1967

26 Workmen's Compensation Act, Toronto, Section 86 (7)

27 *Collective Bargaining Agreement Between International Nickel and the United Steelworkers of America*, July 1975; this agreement provides for such innovative features as an Occupational Health Research Study Group funded by the company.

28 The following references provide examples of current codes of practice and working experience in other jurisdictions: *Occupational Health Committees Code of Practice*, Occupational Health and Safety Division, Saskatchewan Department of Labour, November 1973; *Works Safety Committees in Practice – Some Case Studies*, Ministry of Labour, United Kingdon, HMSO, 1968

29 Brief 139, 23d

30 Brief 139, Section f

31 Transcript, 1067–71, 1102; International Labour Office, *Safety Training for Underground Mineworkers*, Geneva: ILO Occupational Safety and Health Series, 1968, chap. IV, Metal and Non-Metal Mines

32 The Mines Engineering Branch prepares annual summary reports on hoisting accidents. The following table summarizes a sample of data from these reports:

		Proportion of total attributed by cause			
Calendar year	Total number of accidents	Improper functioning of equipment[a]	Error of hoistman	Other human error	Unknown
1971	77	0.57	0.34	0.09	
1972	56	0.57	0.10	0.25	0.08
1973	43	0.23	0.26	0.51	

a Including poor maintenance and improper procedures

33 Mining Act, Section 163; *Handbook of Training in Mine Rescue and Recovery Operations 1973*, Ministry of Natural Resources, 8th ed.
34 In the twenty-six years from 1947 to 1973 there were 401 underground fires and 279 fires on surface. Rescue crews and/or their specialized apparatus worked underground in 96 of these. One life was lost due to asphyxiation.
35 Task Force on Industrial Training, *Training for Ontario's Future*, Toronto: Ministry of Colleges and Universities, Manpower Training Branch, 1972. This report provides an historical review of the role of the provincial government in industrial training and makes extensive recommendations, reference to which will be made below.
36 Transcript, 1163, 1322, 1415, 1482, 1512, 1658, 2706, 3098
37 *Census of Canada, 1971*, Catalogue 94–731, vol. III, Pt 3, Bulletin 3.3–4, June 1975
38 Brief 51, 21
39 Brief 17, appendix F, 8–12. This system, introduced in 1965, appears to have stimulated the interest of the then Department of Labour (Ontario) in miner-training programs through its Industrial Training Branch. See also Brief 9, 1, and Brief 67, 20–1.
40 Brief 52, 14–21 and appendix 8. See also n. 36 and General Advisory Committee on Industrial Training, *Report* Toronto: Department of Labour, 1968.
41 The Ministry of Colleges and Universities, Manpower Training Branch, maintains a master file of the new training modules for mining and for other industrial fields. Typical titles related to drilling are:

Module number	Title	Performance objective
06–08–003–3	Drill rock	To be able to collar and drill holes in rock
06–08–008–1	Operate drill (Jackleg)	To be able to assemble and operate jackleg drill, and to mount steel
03–02–006–3	Fasten rockbelts and anchors	To be able to fasten rockbolts and anchors safety and securely

42 The adoption of the modular system of accredited training in the smaller and particularly isolated mining operations poses serious difficulties. Innovation through district co-operation and the provision of itinerant instructors are possibilities. The Commission emphasizes that the classroom is not a substitute for the mine for the great majority of training.
43 Brief 105 and Exhibit 102
44 Brief 132 and Exhibit 129, 4, para. 5
45 Mining Act, Sections 305 (7), 218 (6)

5

Other environmental hazards at the workplace

In the preceding chapters studies of silicosis and dust, of lung cancer and ionizing radiation, and of accidents at work have been undertaken in some detail. The purpose of this chapter is to survey briefly the status of health problems arising from chemical agents and from the physical agent noise[1] and to examine how the responsibility-system has dealt with these problems.

There is no simple basis for classifying the immense range of biological effects of chemical agents. However, some of their acute and chronic effects may be distinguished. Acute effects result from sudden or short-term intense exposure to agents encountered under accidental circumstances. Chronic disease may result from sustained exposure to levels far below those which produce acute effects. Depending on the particular agent, acute or chronic effects may be fatal.

Conditions underground have been discussed at some length in other parts of this report, but little has been said about the nature of hazards in concentrators, hydrometallurgical plants, smelters, and refineries.[2] Figures 14 to 18 provide simplified flowsheets for the processes that are characteristic of the reduction of ore after it is hoisted.[3] In each diagram, representative sources of chemical and physical hazards are listed. Present metallurgical plants in Ontario must be operated, and new plants must be designed, to enable products to compete in international markets. The Commission has been advised that representative new metallurgical plants in Scandinavia, the United States, and Japan are achieving major improvements in occupational conditions. There is no reason to believe that comparable plants in Ontario are inferior to their counterparts, although conditions in older plants are inferior to those in newer ones.

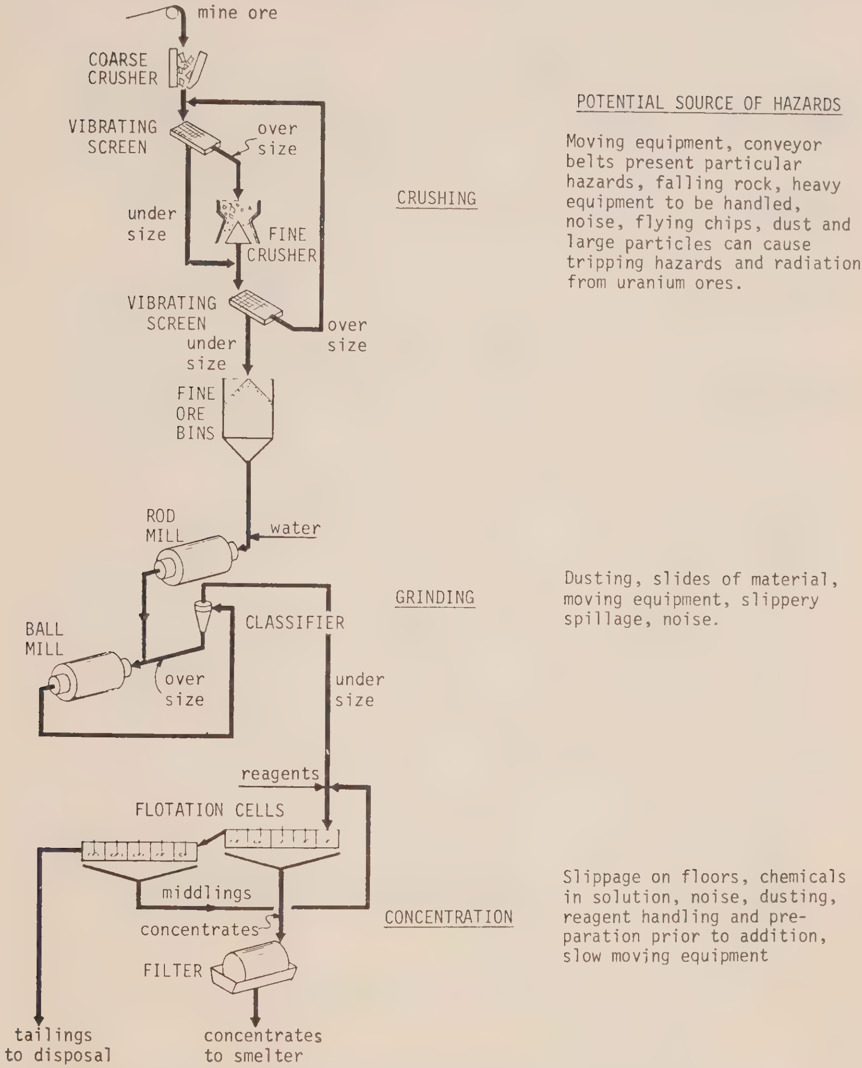


FIGURE 14 Crushing, grinding, and concentration

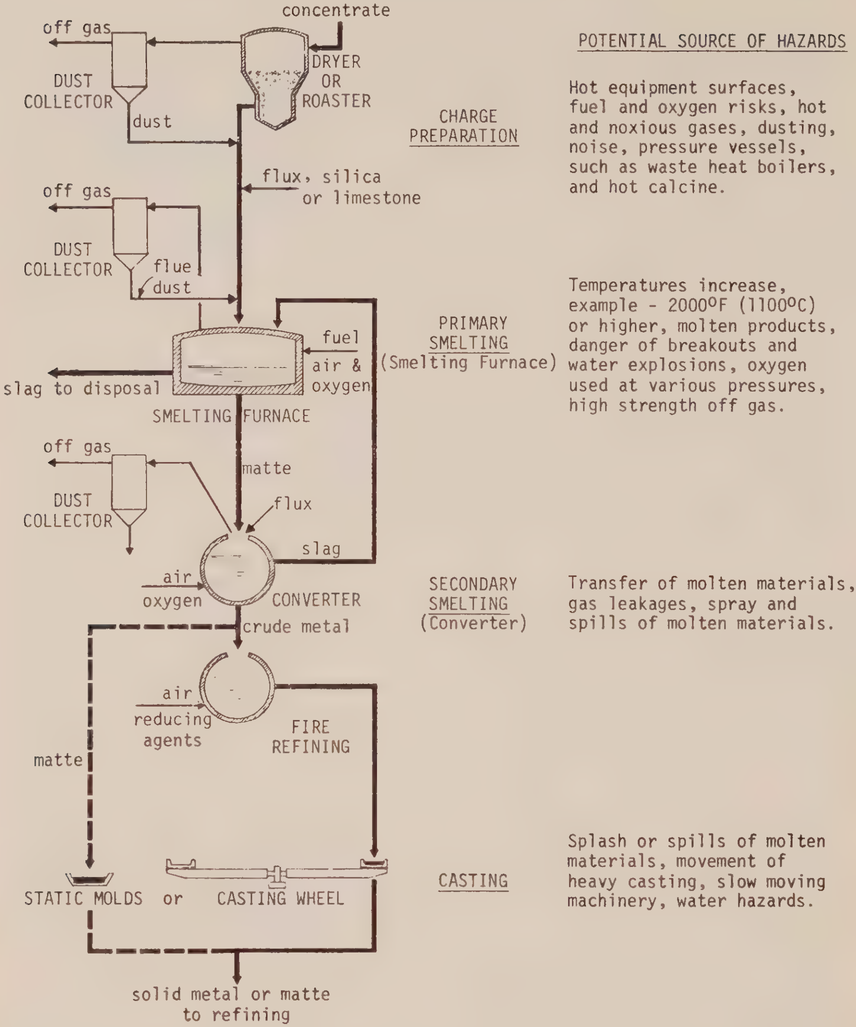


FIGURE 15 Smelting of concentrate

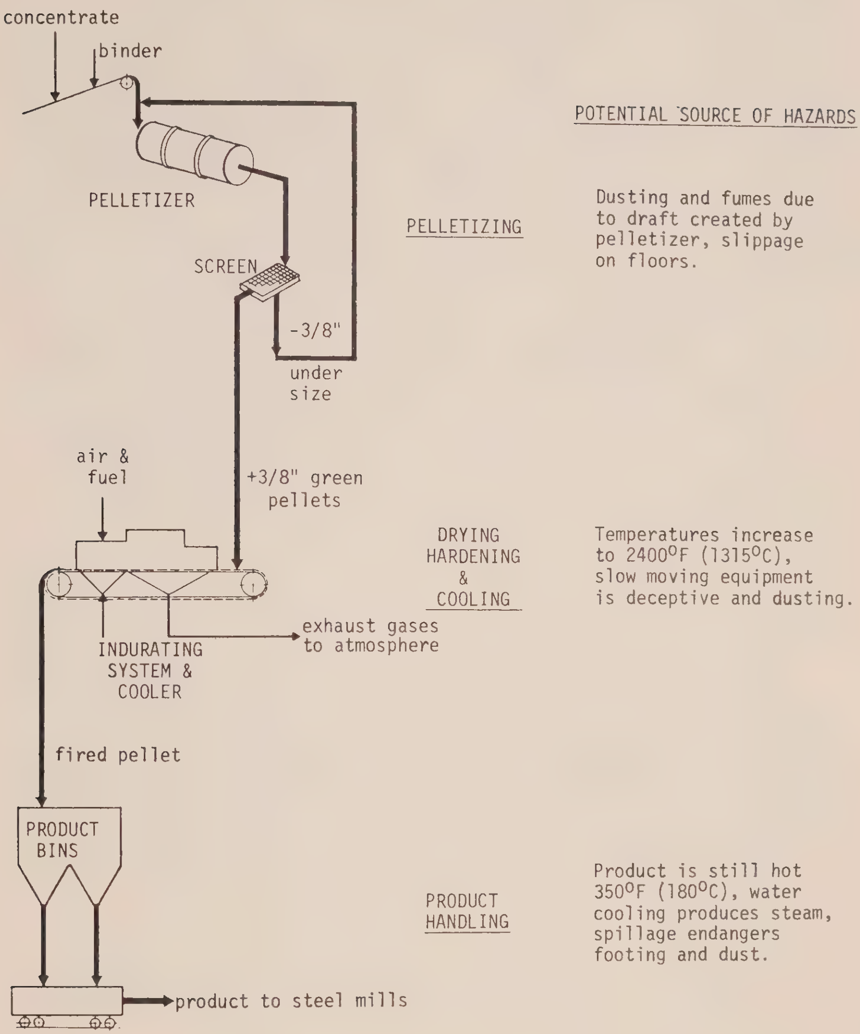
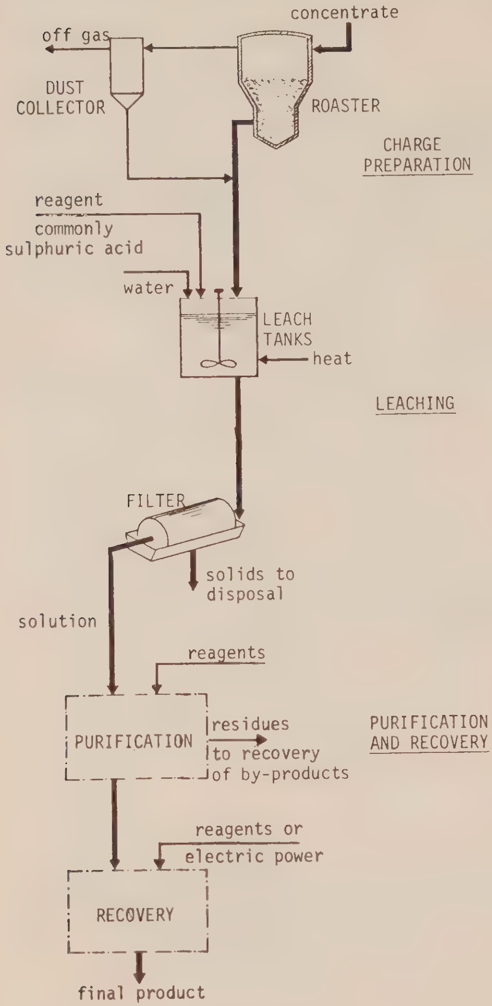


FIGURE 16 Agglomeration of iron ore concentrate



POTENTIAL SOURCE OF HAZARDS

Hot equipment surfaces, fuel and oxygen risks, hot and noxious gases, dusting, noise, pressure vessels, such as waste heat boilers, and hot calcine.

Strong chemicals in large volumes, such as sulphuric acid, ammonia, etc.; solution spills can cause hazardous floor conditions and contaminate the atmosphere, fumes resulting from leaks, and foaming.

Same as listed for leaching with added hazard that dangerous gases may be generated, example, arsine, hydrogen, etc., residues can contain significant concentrations of potentialy hazardous elements such as arsenic and cadmium.

FIGURE 17 Hydrometallurgical treatment of concentrate

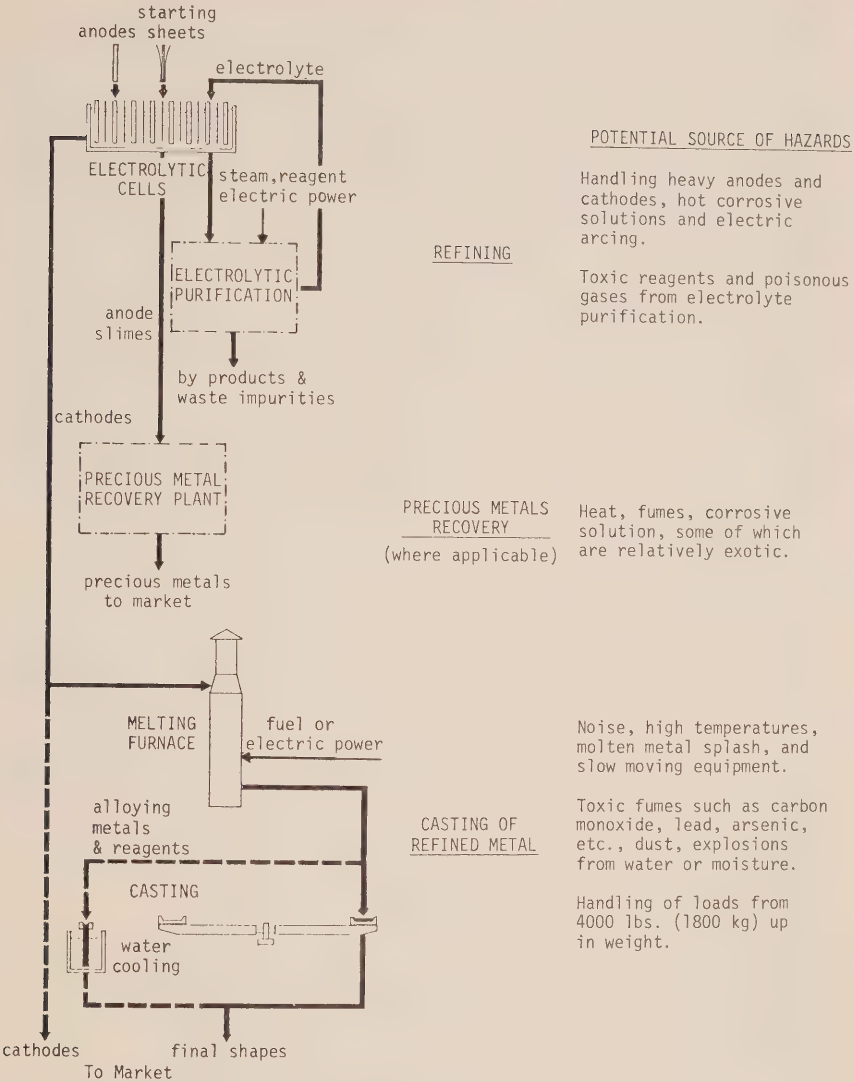


FIGURE 18 Electrolytic refining of metals

THE RECORD OF CHEMICAL AGENTS AS TOXIC SUBSTANCES

Chemical agents acting as toxic substances form a subclass of all hazardous materials, which include flammable, explosive, corrosive, and radioactive materials. Toxic substances occur in the form of dusts, fumes, mists, liquids, vapours, and gases. In normal operations they are encountered underground as blasting fumes and in the exhausts of drills and diesel engines. In reduction or metallurgical plants they occur as process dusts, fumes, and gases such as nickel oxide, sulphuric acid, and sulphur dioxide and as liquids and vapours associated with hydrometallurgical flotation agents and process solvents. In addition, many different chemicals are handled in the course of supplying reagents to processes and in servicing equipment through lubrication, cleaning, repairing, painting, and so on. A complex variety of toxic substances may be generated as chemical reaction products when different materials are welded. If chemicals are spilled at or leak into workplaces they may react in unintended ways with other materials, especially at high temperatures. Explosions and fire generate unexpected toxic products.

Toxic substances may be absorbed into the body through the skin, by ingestion into the gastrointestinal tract, and by inhalation into the respiratory system. The majority of these substances are eventually excreted from the body in a chemically different form, but some do accumulate. Toxic substances produce a great variety of biological effects, ranging from reversible tissue damage to severe systemic effects which interfere with normal body functions and may be fatal. Because many toxic substances are inherent to industrial activity, including mining, there have been extensive efforts made to determine permissible levels of human exposure, expressed for example as Threshold Limit Values (TLVs).[4] In Table 53 are listed TLVs for representative gases and vapours and for dusts, fumes, and mists. A substantial number of these are the causative agents currently involved in injuries from the inhalation of a toxic material, from contact dermatitis, and from contact burns. The occurrences of such injuries will be considered.

To establish the status of such effects in the population of mine workers the Commission first reviewed all fatalities for the decade 1965–74, and the records of the Workmen's Compensation Board for all non-fatal medical aid and lost-time compensable injuries attributed to acute inhalations and contact dermatitis for the three-year period 1972–4. Of the 213 fatalities in mines for the decade 1965–74, five, or about 1/40 of the total, were caused

by toxic effects. Three were cases of asphyxiation in underground operations, of which one was caused by carbon monoxide and lack of oxygen in a highly localized fire and two were caused by oxygen deficiency in poorly ventilated locations. Of the remaining two, one was caused by acid burns and the other by flash burns from magnesium.

The substances involved in non-fatal inhalation of toxic materials are listed in Table 54 in order of most frequent occurrence together with representative circumstances of encounter. Although the locations of the incidents within the different sectors of operations are varied, the largest number of events occurs in reduction plants including concentrators where toxic substances are inherent to the operation of processes as depicted in Figures 14 to 18. Yet it is a matter of concern that the inhalation of blasting fumes accounts for nearly one-third of all events.[5] Blasting practices are clearly at issue. Further, it is surprising to note in the brief from the Canada Centre for Mineral and Energy Technology that adequate funds have not been available to permit research to be actively pursued on the generation of fumes from explosives so that quantitative requirements for ventilation to remove blasting fumes could be accurately established. Table 54 shows that many toxic substances besides blasting fumes contribute to inhalation injuries. In round figures the average number of compensable inhalation injuries over the three years 1972–4 was 11 per annum and the number of medical aid cases was 26 per annum. The compensable injuries are thus about one-third of the total of compensable and medical aid injuries. The compensable injuries involved a total lost time of 159 days per annum and the average duration of lost time for these injuries was 14.5 days.

Contact dermatitis denotes inflammatory reaction of the skin to some external agent acting either as a primary irritant or as an allergic sensitizer. The manifestations of occupational dermatitis in mining have been reviewed by Rogan.[6] In Table 55 is a list of the substances involved in contact dermatitis, ranked in order of the number of events, together with representative circumstances of encounter. Caustics and acids, nickel, cyanide, and arsenic are the major agents associated with dermatitis. Substances producing dermatitis may either wet the skin directly or be airborne. In round figures, the average number of compensable cases of contact dermatitis has been 7 per annum, and these have accounted for 198 days of lost time per annum or 28 days per case. The number of medical aid cases averaged 12. Thus, as with inhalations, the number of compensable injuries is about one-third of the total of compensable and medical aid cases.

The Commission has also examined the records of the Mines Accident

TABLE 53

Threshold Limit Values for representative toxic substances that may be encountered in mining operations

	Selected gases and vapours		Selected dusts, fumes, and mists	
Substance	Parts per million (ppm)	Milligrams per cubic metre (mg/m^3)	Substance	Milligrams per cubic metre (mg/m^3)
Acetone	1,000	2,400	Antimony and compounds (as Sb)	0.5
Ammonia	25	18	(Antimony trioxide*)	(0.05*) production
Arsine	0.05	0.2		(0.25) handling
Benzene (benzol)* – skin C	25 (10*)	80 (30*)	Arsenic and compounds (as As)	0.5
Carbon dioxide	5,000	9,000	(Arsenic trioxide*)	(0.05*) production
Carbon monoxide	50	55		(0.25) handling
Carbon tetrachloride – skin	10	65	Asbestos	[5 fibres/cc > 5 microns in length]
Chlorine	1	3	Cadmium, metal dust and soluble salts (as Cd)*	0.2 (0.05*)
Ethylene glycol	100	260	Cadmium oxide fume (as Cd) C	0.05
Formaldehyde C	2	3	Chromic acid and chromates (as CrO_3)	0.1
Hydrogen chloride C	5	7	Cobalt, metal fume and dust	0.2
Hydrogen cyanide – skin	10	11	Copper:	
Hydrogen fluoride	3	2	dusts and mist	1
Hydrogen sulphide	10	15	fume	0.2
Nickel carbonyl*	0.001 (0.05*)	0.007 (0.35*)	Fluoride fume (as F)	2.5
Nitrogen dioxide C	5	9	Iron oxide fume	5
Nitroglycerin – skin	0.2	2	Iron, soluble salts (as Fe)	1
Ozone	0.1	0.2	Lead, inorganic fumes and dusts (as Pb)	0.15
Perchloroethylene	100	670	Manganese and compounds (as Mn) C	5
Phosgene (carbonyl chloride)* C	0.1 (0.05*)	0.4 (0.2*)	Mercury (all forms except alkyl) (as Hg)	0.05
Phosphine	0.3	0.4	Nickel, metal and insoluble compounds (as Ni)	1
Sulphur dioxide	5	13	Oil mist, particulate	5

Toluene -2, 4- diisocyanate c	0.02	0.14	Platinum, soluble salts (as Pt)	0.002
Toluene (toluol) – skin	100	375	Selenium compounds (as Se)	0.2
			Silver, metal, and soluble compounds (as Ag)	0.01
			Sulphuric acid	1
			Tellurium	0.1
			Uranium (natural) soluble and unsoluble compounds (as U)	0.2
			Vanadium (V_2O_5, as V)	
			dust	0.5
			fume c	0.05
			Zinc oxide fume	5
			Zirconium compounds (as Z_r)	5

NOTE: For representative circumstances of encounter see tables 54 and 55. An asterisk indicates an intended change. A 'c' indicates that the TLV is a ceiling value.

SOURCE: TLVS, ACGIH 1975

TABLE 54

Chemical substances involved in acute inhalations for the three-year period 1972–4 (in order of most frequent occurrence)

Toxic agent	Number of events: Total	Compensable[a]	Medical Aid[b]	Representative constituents	Representative circumstances of encounter
Blasting fumes	33	9	24	carbon monoxide, nitrogen dioxide, ammonia	driller (8), driller helper, skip feederman, stope boss, chute blaster, miner, diesel mucking, construction leader
Carbon monoxide	14	3	11	–	driller in raise, conveyorman working over oil burner, mechanic on truck, mechanic repairing scooptram, bricklayer in furnace, crane operator, miner underground, scooptram operator, mucking with fans off
Chlorine gas	11	3	8	–	changing cylinder, process chemist spill, mechanic removing chlorinator, cementation operator opened chlorine valve, fumes from absorption tower, pressman transferring chlorine from storage to settler tank
Solvent fumes	9	1	1	acetone, toluene, perchloroethylene, fluorinated and chlorinated hydrocarbons in ethylene glycol, varsol	miner painting, pipefitter, labourer using grease solvent, preparing printing mandrel, garage mechanic, diesel loaderman, instrument mechanic checking level
Sulphur dioxide gas	8	4	4	–	copper refinery, cementation man in electrolytic department, furnace helper controlling metal flow, feeder at slimes dryer, crusher helper, welder, electrician near flash furnace

Report of the Royal Commission on the Health and Safety of Workers in Mines

<u>CORRECTIONS</u> <u>Table 54</u> <u>Page 192-3</u>

Toxic Agent	Number of Events	
	Compensable	Medical Aid
Solvent fumes	1	8
Nickel carbonyl gas	1	4
Acid Mist	1	3
Smoke	1	3

All other data including all subtotals and totals are correct. There was an error of transposition between compensable and medical aid events for the above substances only.

James M. Ham
Commissioner
20 August 1976

Welding fumes	5	2	3	zinc fumes, manganese fumes, other welding fumes	cutting zinc bar at primary crusher, burning galvanized tin in underground garage, burning magnesium core crusher lever with embedded zinc
Nickel carbonyl gas	5	~~4~~ 1	~~1~~ 4	–	technician installing piping, worker in sump
Acid mist	4	3	1	chromic acid, sulphuric acid, and ammonium chloride	electrician in refinery, labourer stripping zinc from cells, pipefitter, mandrel preparer
Smoke	4	3	1	–	fireman, balling disc operator, maintenance mechanic in refinery
Hydrogen sulphide	4	2	2	–	repairs to autoclave in refinery, labourer in copper sulphate plant
Ammonia	2	1	1	–	maintenance mechanic at valve
All others	10	4	6	acid battery fumes, antifreeze fumes, cyanide and hydrochloric acid, manganese fumes, ammonium sulphide hydrogen fluoride	sandblaster inhaled antifreeze, cleaning a lead circuit, installing crusher plate, filterman fighting fire, labourer pumping sulphide, welder working on cell screens, garage mechanic, forklift operator inhaled battery fumes, student acid spill
Total	109	32	77		
Average number of events per annum (rounded)	36	11	26		

a A compensable event is one that involves the loss of one or more days at work following the date of the event.
b A medical aid event is one for which there is no lost time at work other than on the day of the event, but an attending physician renders service which is paid for by the Workmen's Compensation Board.

TABLE 55

Chemical substances involved in cases of contact dermatitis for the three-year period 1972–4 (in order of most frequent occurrence)

Toxic agent	Number of events			Representative constituents	Representative circumstances of encounter
	Total	Compensable	Medical aid		
Caustics and acids	15	4	11	sulphuric acid and lime, bone ash, acids in electrolytic refining of zinc and copper, soda ash, cyanide	cleaning floors, process labour, cell operator, contract carpenter, acid plant supervisor
Nickel	11	9	2	nickel dusts, nickel salts, nickel and magnesium oxide, nickel hydrate, nickel sulphate, nickel chloride, slimes	shear labourer, process labour, floor labour, washing machine operator
Cyanide	6	1	5	cyanide solution and dust, lime	mill operation, maintenance welder, mill mechanic
Arsenic	6	0	6	arsenic dust	maintenance electrician, mill mechanic, mill helper, roaster operator, master mechanic supervising at baghouse
Industrial chemicals	5	2	3	amine, copper electrolyte, Dowfroth, copper sulphate, sodium amyl xanthate, ammonium nitrate and fuel oil, varsol, ammonia	helper on metallurgical process, process labour in mill, mill maintenance, blaster
Oil	3	1	2	machine oil, hydraulic oil	driller, maintenance mechanic

Lime and Cement	2	0	2	lime dust in combination with mill chemicals	mill helper and filter operator, installation mechanic
Lead (absorption in blood)	1	1	0	lead	cleaning lead plates in lead-zinc plant
Rubber	2	1	1	rubber respirators, rubber boots	assembler, watering muck in rubber boots
Solvent	1	1	0	lacquer thinner, varsol	painter
Nickel solvent	1	0	1	nickel solvent	electrician cleaning bearing
Plastics	1	0	1	epoxy resins	electrician
Inks and dyes	1	0	1	acetone, toluene, epoxy ink	preparing mandrel
Glues and paste	1	0	1	glue	electrician
Miscellaneous (prickly heat)	2	1	1	temperature, barium powder	roaster department, cleaning washroom
Total	58	21	37		
Average number of events per annum (rounded)	19	7	12		

TABLE 56

Non-fatal compensable injuries resulting from acute encounters with toxic chemicals (averages for three-year period 1972–4)

		Number of injuries per annum				
Section of operations	Average population	Inhalations	Contact dermatitis	Chemical burns	Absorption in eyes	Total
Underground	12,000	3.7	0.7	5.0	3.3	12.7
Shops and surface	15,800	2.7	0.7	1.6	1.3	6.3
Reduction plants	7,000	4.3	5.6	6.3	11.0	27.2
All	34,800	10.7	7.0	12.9	15.6	46.2

SOURCE: Workmen's Compensation Board, Mines Accident Prevention Association

TABLE 57

Non-fatal compensable injuries: proportion resulting from acute encounters with toxic chemicals

Sector of operations	Non-Fatal Compensable Injuries Per Million Man-Hours: Injuries from toxic chemicals[a] (1)	All compensable injuries[b] (2)	Ratio (1)/(2)
Underground	0.5	66.9	1/134
Shops and surface	0.2	16.5	1/83
Reduction plants	1.9	41.2	1/22
All	0.7	44.9	1/64

a Data from Table 56 with one man-year being two thousand hours
b Data from Table 42, where 'all' includes open pits as well as the categories shown in this table

Prevention Association for compensable injuries produced by acute encounters in which toxic chemicals are ingested, enter the eyes, or produce chemical burns of the skin.[7] The average number of events per annum during 1972–4 for each of these problems is noted in Table 56. The greatest frequency is in eye injuries caused by chemicals in reduction plants. Greater attention ought to be paid to the meticulous use of eye protection in all operations.[8]

The occurrence of all non-fatal compensable events attributed to toxic substances by location is summarized in Tables 56 and 57. For all locations the average number of such events per year is 46.2. The total of non-fatal compensable injuries and medical aid cases per annum is expected to be about 150, or three times the number of compensable cases. Table 57 shows that 1 in 134 injuries underground is related to toxic chemicals. In shops and surface units the number is 1 in 83 injuries, and in reduction plants it is 1 in 22 injuries. All the cases reported were clearly ascribable to the categories used. But because of inherent difficulties in classifying injuries there may be some underascertainment of injuries that should be classified here as being caused by toxic substances. The Commission believes that the round figures 1 in 120 for underground, 1 in 75 for shops and surface, and 1 in 20 for reduction plants are reasonable indicators of the direct involvement of toxic chemicals in lost-time injuries arising from acute encounters at the workplace. There is some evidence that medical

aid cases occur approximately twice as often as do compensable injuries. There are undoubtedly many other incidents with chemicals that involve temporary discomfort, irritation, or annoyance which do not require the services of an attending physician or involve loss of time at work on a day following the incident and hence are not included in the records of the Workmen's Compensation Board.

An examination of the circumstances of encounter in Tables 54 and 55 will suggest that the kind of subpopulation of workers at risk is substantially less than the total number of workers. The risk of a given type of injurious acute encounter with toxic substances cannot readily be estimated without an accurate knowledge of patterns of work. These tables also show that the variety of chemicals involved is large, and in view of the many different effects they may have on a person it is not surprising that workers have expressed concern about the possibility of damage to health, about the care with which they are identified and handled, and about the adequacy of information about the hazards involved in their use.[9]

THE CONTROL OF TOXIC SUBSTANCES

Chemical agents are inherent in the production and refining of metals. They occur as normal products of chemical reactions, as reagents added to processes, and as substances used in the construction, servicing, and repair of equipment and processes. They become most dangerous during unanticipated leaks and spills, when additional products of unexpected chemical reactions may appear as a result of fire, explosion, and so on.

About both potential risks and actual events it is desirable to have knowledge of

- the kinds and amounts of substances that can be expected to be present at a given place of work under normal and upset conditions;
- the hazards to human health of each substance and as far as possible all toxic combinations thereof, including Threshold Limit Values or their equivalent;
- the available means and standard practices for limiting the presence of toxic substances;
- the kinds, amounts and concentrations of substances that are actually present at the workplace at any time;
- the persons who are likely to encounter the substances at work;
- the frequency and duration of intervals at which these persons may be expected to be at risk;
- the exposures actually experienced by persons at risk;

– the medical procedures for assisting a person who experiences an acute encounter;
– the occupational history of persons subject to acute exposures; and
– the developing state of health of exposed persons.

The mining industry lacks complete information on all these points. The provisions of the Mining Act[10] are general and incomplete, and to the Commission's knowledge no relevant codes of practice have been issued by the Mines Engineering Branch to guide the inspectorate, the industry, and the workers on these matters. Major reliance has been placed on the self-regulatory character of the internal responsibility-system.

The metallurgical plants present the greatest ongoing risks from chemical agents and so deserve particular attention. The issues to be considered are the development of metallurgical audits, codes, and schemes of practices and the training of workers.

METALLURGICAL AUDIT

It is essential to know the quantity of known hazardous substances present in a mining operation at any given time and to know how the substances enter the operations and how they leave it. Knowledge of this kind constitutes an audit of material which is usually on the basis of mass. It is standard practice in the operation of metallurgical plants (reduction plants) to conduct by careful sampling and analysis an audit of the origin, holdup, and destination of the major chemical elements and compounds involved in valuable products. The Commission has been advised that a metallurgical audit is increasingly important with respect to minor elements that may be injurious to the health of workers. Metallurgical plants have as inputs crushed and ground ores, water, heat, and reagents as shown in Figures 14 to 18. As the processes operate, substances leave the system as metal products containing impurities, tailings from processes, and the washdown of spills. They leave fixed in slags or in various bleed streams vented to the external environment through ventilation stacks, louvres, and chimneys. These bleed streams may contain dusts, fumes, gases, steam, and so on.

In addition to the major elements, the internal metallurgical system will contain at any given time a holdup mass of minor elements such as lead, arsenic, selenium, tellurium, cadmium, and antimony. The levels of these toxic elements depends on the bleed and effluent streams in use. As external environmental standards of air pollution have been made more rigorous and recovery objectives for valuable products have been raised, traditional bleed streams have increasingly been recirculated to the internal

metallurgical processes. As a consequence the relative amounts of different toxic minor elements may increase or decrease significantly at different locations in the system because of buildup or unexpected losses. The potential risks from leakage and spills from process units into locations of work may therefore change significantly, and the changing risks may not be recognized if a metallurgical audit of minor elements is not carried out. The Commission therefore recommends:

That there be a statutory requirement for a metallurgical audit of origin, holdup, and destination of potentially dangerous compounds of minor elements such as lead, mercury, arsenic, selenium, tellurium, cadmium, and antimony to be conducted quarterly in all reduction plants on the basis of extended standard monthly sampling and analytical procedures and that a copy of this audit be sent to the Occupational Health and Safety Authority.

The purpose of such an audit is to alert management to any significant changes in the distributions of minor elements that require further investigation. In addition to this audit it is recommended:

That there be a statutory requirement for an annual audit of use by mass of toxic and hazardous reagents and that a copy be sent to the Occupational Health and Safety Authority.

The intent of such an audit is to identify significant changes in the scale of use of reagents. For example, the use of solvent extraction methods has led to the presence of large masses of flammable substances. While the potential hazards are clearly recognized, there should be a record of their changing presence.

When new metallurgical plants are being designed using pilot plants it is desirable that the conventional programme be expanded to measure factors which may have an impact on the working environment. The character and content of fumes, dusts, and intermediate products should be analysed with particular emphasis on minor elements. The resulting information may be used for designing ventilation systems and establishing preliminary operating procedures and safety standards for a commercial-scale plant whose development may take from three to eight years. The Commission therefore recommends as a practice of occupational health assessment for new plants:

That pilot plant studies used to develop processes and preliminary operat-

ing procedures be extended to include the measurement of factors likely to have an impact on the health and safety of the environment for work.

The Ministry of Health in its brief to the Commission has indicated its intent to conduct occupational health assessment studies for new plants and major revisions to existing plants in co-operation with industry and related ministries.[11] The Commission strongly endorses this policy and believes that it should be given a statutory basis in the manner described in chapter 6.

CONTROL OF THE USE OF REAGENTS AND SERVICING CHEMICALS

For these substances there are questions of labelling, storing, procedures for use and cleanup, and treatment in the event of acute encounter. The Mining Act contains the following general provisions:

199 Any dangerous, flammable or explosive material or substance in a solid, liquid or gaseous state or any combination of them, other than manufactured explosives and blasting agents, that is kept, stored or handled, in a plant,
(a) shall be kept in a container that is suitable having regard to the nature and state of the material or substance; and
(b) shall be kept apart or insulated from any reasonably foreseeable source of ignition or from temperatures likely to cause combustion;
and where the material or substance is kept, stored or handled for a purpose other than immediate use, it shall be kept, stored or handled,
(c) outside any building;
(d) in a building not used for any other purpose; or
(e) in a fire-resistive compartment satisfactory to the district mining engineer as to location and construction.

222(1) At every plant where poisonous or dangerous compounds, solutions or gases are used or produced, there shall be kept in a conspicuous place, as near the compounds, solutions or gases as is practicable, a sufficient supply of satisfactory antidotes and washes, and there shall be installed eye wash fountains and, where necessary, safety showers, for treating injuries received from such compounds, solutions or gases.
(2) Such antidotes and washes shall be properly labelled and explicit directions for their use affixed to the boxes containing them.

223(1) Where an acid or poisonous compound or any other material that is likely to endanger the health of an employee is produced, transferred, used or stored in a plant, due provision shall be made to reduce to a minimum the hazard of handling or storing such material.

TABLE 58

Sample sheet for hazardous material control

Product: Caustic soda
Use or function: Cleaning agent
Maker: Canadian Industries Ltd
Vendor: Canadian Industries Ltd

Key = Safe
0 With care
x Dangerous

	Rating	Respirator	Air changes	Clothing	Remarks
Storage	x				Away from combustibles or organics
Handling	x	*	*	*	Ventilate freely – Wear filter or dust type respirator, chemical goggles, rubber gloves, protective clothing.
Use					
Clean-up	x	*	*	*	Wash away with plenty of water.
Disposal					
Fire	x				Non-flammable – can cause ignition of combustibles or organics
Combustion products					
Explosion	x				Forms explosive gases on contact with aluminum, tin, zinc, etc.
Room temperature vapours	x				TLV 2 mg /m^3
Toxicity (ACGIH)	x				
Corrosion	x				

First Aid: Eyes, skin – flush with water for 15 mins minimum – remove contaminated clothing. If inhaled or swallowed – contact doctor immediately.

SOURCE: Reproduced with permission of the MAPAO

(2) Where the provisions taken under subsection 1 do not remove the hazard, personal protective equipment shall be worn by the person exposed to the hazard.
(3) Where such material is present, there shall be posted in a conspicuous place, when so required by the chief engineer, notices stating the dangers involved and the precautions to be taken.
(4) Where required, the employer shall provide the chief engineer with accurate information regarding the percentage of any harmful ingredient in such material.
(5) Any person who, for use in a plant, manufactures, distributes or purchases any material that contains benzol, carbon tetrachloride, lead or other ingredient that is deemed dangerous to health by the chief engineer, shall indicate the presence of such ingredient by a label lettered in legible type, distinctly visible and affixed to each package or container thereof.
(6) The chief engineer on the advice of the director of the Environmental Health Branch of the Department of Health, may require at specified intervals by qualified physicians and at the expense of the employer a physical examination of any person employed in a plant having a process that the chief engineer considers is likely to endanger such person's safety, and the physician shall forthwith send or cause to be sent to such director a report of the examination in a form suitable to the chief engineer.
(7) The examination required under subsection 6 shall be prescribed by such director and may include an x-ray examination and blood or other tests.

These sections deal in a general manner with storage, antidotes, wash facilities, handling, posting of information about dangers and precautions, provision of information by the employer to the Mines Inspectorate, labelling, and medical surveillance. The Mines Engineering Branch has issued no codes of practice in these matters.

The MAPAO first issued in 1969 a brochure listing properties of airborne contaminants in reduction plants and began issuing standard forms for recording information about hazardous substances in 1974. The introduction of formalized programmes of control of hazardous substances in the industry appears to have been relatively recent.[12] An example of an information sheet for a toxic substance as prepared for hazardous material control is given in Table 58. Some companies have issued booklets on reagents and chemical hazards to all employees at particular plants.[13] Further, the Ministry of Health has recently commissioned tripartite task groups to prepare guidelines for the labelling and handling of the chemicals.[14] Their reports identify the basic elements of these problems.

The variety and amount of substances in use as servicing chemicals is growing rapidly. Believing it is important for each company to maintain a register of such chemicals currently in use, showing both trade name and chemical formula, the commission recommends:

That there be a statutory requirement for each mining company to maintain a register of servicing chemicals involved in any personal encounter associated with a medical aid or compensable injury; that the register specify both trade name and chemical composition and identify all known toxic chemical constituents; that the register include an audit by mass of annual use; and that a copy of this register be provided to the Occupational Health and Safety Authority;

and further

That there be a statutory requirement for each mining company to give the Occupational Health and Safety Authority notice of intent to introduce any new reagent or servicing chemical whose toxic characteristics are not known.

The Occupational Health and Safety Authority should have the statutory power to require the analysis of any chemical substance in use and biological testing for toxicity.

CODES AND SCHEMES OF PRACTICE

For the control of chemical agents the Commission believes that schemes of practice, as referred to in chapter 2, are very important.[15] Knowledge of these should be included as part of the training of all who operate and maintain metallurgical processes. A review of Tables 54 and 55 will confirm that maintenance workers are commonly involved in injuries from toxic substances. Maintenance workers employed on diverse process units should have a clear understanding of the hazards of each operation in which they are assigned to intercede and therefore should have access to and knowledge of codes and schemes of practice. Worker-auditors, members of the Joint Health and Safety Committee and of the Mines Inspectorate, and the workers directly involved should all have access to the appropriate schemes of practice. The Commission thus recommends:

That with respect to codes of practice and schemes of practice the principles of recommendations 8, 9, and 10 [*as listed in appendix* A] *be extended 1/ to the maintenance and operation of mills and metallurgical plants as these activities relate to the leaking and spilling of toxic substances and hot materials into workplaces; 2/ to the handling and use of reagents and servicing chemicals and to the consequences of their leaks and spills.*

Schemes of practice should provide relevant information about the risks of acute encounter with toxic substances. They should outline standard practices for avoiding and controlling leaks and spills and for cleaning up when they occur. Further they should give explicit instructions on how to assist any person who experiences an acute encounter likely to cause injury.

EDUCATION AND TRAINING FOR THE DESIGN AND OPERATION OF METALLURGICAL PLANTS

The Commission believes there is need in the education of metallurgical engineers and related disciplines to strengthen concern for, and control over, the impact of processes on persons at work. In a survey of engineering schools in the province the Commission found no instance of an established active interplay between engineers and occupational health specialists in faculties of medicine, although recent initiatives are evident at McMaster and Toronto. It is recommended:

That engineering schools review and redefine their responsibility to the profession to ensure that graduates are more keenly aware of and responsive to the impact of technological design upon the occupational health and safety of workers;

That resources for joint research and teaching by specialists in occupational and environmental health in faculties of medicine and engineering be given high priority by both the universities and government.

The broad issue of training and supervision of workers has been addressed in chapter 4; the principles of co-ordination for the performance of work outlined there apply specifically in the operation of metallurgical plants.

Because of the dynamic complexity of metallurgical plants there is special need for a high degree of co-operation, communication, and technical understanding between employees, supervisors, managers, and technical staff if the systems are to operate efficiently and safely. There is a much larger measure of dynamic interdependence than in the sequentially separable operations of underground mining. On the basis of its hearings and investigations, the Commission is of the view that the authority and responsibility of the first-line supervisor is not always sufficiently well defined to enable him clearly to exercise his duty to identify and to ensure

the correction of anomalous working conditions. This point has been discussed in chapter 4.

In the handling of interactive metallurgical processes all employee groups need to have training in both theoretical and practical aspects of the operations for which they are responsible. Such training is necessary to create capacity to 1/ interpret operating and test data correctly; 2/ recognize hazards in abnormal conditions arising out of the interactive characteristics of the processes; 3/ cope with unusual conditions that arise.

Existing training programmes vary from employer to employer, tending to restrict themselves to very specific functions and not to cover the broader interactive aspects of the processes; nor do they supply a great deal of the theoretical background required to interpret data and to cope with abnormal situations. The worker thus may not have the knowledge to reach beyond day-to-day occurrences on the job. To improve the circumstances of training the Commission strongly endorses the modular schemes of training being operated in certain metallurgical plants[16] and, emphasizing the recommendations in chapter 4, encourages the development of provincially accredited systems of modules. The Commission believes there is a need to develop a set of modules based on the hazards of specific toxic substances, a set that can be combined to match the sequence of risk situations that a maintenance worker may be expected to encounter. The Commission therefore recommends:

That profiles of risk-encounter for toxic substances be developed by examining the work patterns of maintenance workers, and that modular training be adapted to such profiles.

MONITORING AND MEDICAL SURVEILLANCE FOR ACUTE ENCOUNTERS WITH TOXIC SUBSTANCES

So far the problems of toxic substances have been treated in terms of acute encounter. Acute encounters and chronic exposures call for complementary processes of monitoring and medical surveillance. The special requirements for chronic exposures will be discussed at the end of this chapter. Although accidental acute encounters cannot by their nature be monitored, the Commission recommends:

That at any location of regular work where acute encounters with toxic substances repeatedly occur as a result of leaking, recirculating, or spilling from metallurgical and milling processes, there be a statutory requirement

for the installation and use of equipment for the continuous monitoring of the substances involved;

That a record of the substances and human effects of acute encounters with toxic substances leading to medical aid and compensable injuries be maintained in the occupational health records of each worker at the company level;

That at five-year intervals the Occupational Health and Safety Branch commission a review of the status of the health of samples of persons who are at high risk from acute encounters with toxic substances, including as necessary intensive medical surveillance.

The need and responsibility for central occupational health records necessary for epidemiological studies for both acute and chronic exposures to toxic substances will be discussed after the following review of evidence of chronic effects.

THE EFFECT OF CHRONIC EXPOSURE TO TOXIC SUBSTANCES

The chronic effects of a few substances, such as free silica and lead, are relatively well known, but for the great majority of chemical agents used at the workplace today there is scant data available upon which to establish accurately the range of their long-term effects on humans. Documentation for Threshold Limit Values is based on experiments with animals, on evidence of acute effects observed in the exposure of persons at work, and on long-term studies. Studies of the latter type based on reliable measurements of toxic substances, clearly delineating the effects of a specific agent, and in particular separating the effects of smoking are relatively few in number. This area of study is a major frontier in environmental and occupational health. The Commission believes that the issues related to the recognition, prevention, and compensation of chronically induced industrial disease are becoming centrally important in occupational health. At the same time it is to be emphasized that, in mining, disabling and fatal accidents cause far greater loss in immediate human well-being than do the industrial diseases currently recognized for compensation.

It has been noted that the air breathed at workplaces in mines and plants typically contains combinations of such toxic substances as mineral dusts and sulphur dioxide or mineral dusts and diesel fumes, and the majority of

workers smoke cigarettes. Moreover, diseases such as lung cancer and chronic bronchitis, some cases of which are believed to be attributable to industrial exposure, occur commonly in persons not exposed in mines and mineral plants. Hence, even with well-founded data collected at the workplace there is substantial difficulty in discerning the influence of a particular agent on the population at risk and extreme difficulty in identifying the cases resulting from work exposure. The complex problems of ascribing disease to industrial workplaces at which combinations of contaminants occur can be placed in some perspective by reviewing briefly the investigations conducted by the Ministry of Health in identifying industrially induced diseases and the record of compensation provided by the Workmen's Compensation Board.

The Workmen's Compensation Act defines industrial disease as follows: ''industrial disease'' means any of the diseases mentioned in Schedule 3 and any other disease peculiar to or characteristic of a particular industrial process, trade or occupation.'[17] The Board's authority to compensate derives from the following sections of the Act.

118(8) If the employee at or immediately before the date of the disablement was employed in any process mentioned in the second column of Schedule 3 and the disease contracted is the disease in the first column of the Schedule set opposite to the description of the process, the disease shall be deemed to have been due to the nature of that employment unless the contrary is proved, but, except where the Board is satisfied that the disease is not due to any other cause than his employment in Ontario, no compensation is payable under this section unless the employee has been a resident of Ontario for the three years next preceding his first disablement.

Under this section, a defined schedule[18] of disease conditions related to specified substances and processes is accepted automatically as constituting industrial disease. Silicosis caused by silica dust is covered by Schedule 3; diseases such as chronic bronchitis and emphysema are not.

118(1) Where an employee suffers from an industrial disease and is thereby disabled or his death is caused by an industrial disease and the disease is due to the nature of any employment in which he was engaged, whether under one or more employments, the employee is or his dependents are entitled to compensation as if the disease was a personal injury by accident and the disablement was the happening of the accident, subject to the modifications hereinafter mentioned or contained in the regulations, unless at the time of entering into the employment he has wilfully and falsely represented himself in writing as not having previously suffered from the disease.

Under this section the Board is free to render interpretive judgments on what is to be recognized as an industrial disease. To assist it in performing this role, the Board has an advisory medical staff which maintains close liaison with occupational health and industrial hygiene specialists in the Ministry of Health, with the Ministry of Natural Resources, and with industry.

In the following analysis the record of the performance of the responsibility-system in responding to problems of identifying and attributing diseases caused by chronic exposures and in dealing with the concomitant issues of records and research in occupational health is critically important.

CANCER OF THE RESPIRATORY SYSTEM

In Table 59 is a record of the cases of cancer among workers in mines that were compensated by the Workmen's Compensation Board up to November 1975. Of 178 cases, eighteen were cases of lung cancer attributed to uranium mines. In chapter 3 it was estimated that in these mines to the end of 1974 there has been an excess of observed over expected cases of lung cancer of about forty-five.[19] A further twenty-two cases of lung cancer were attributed to a silver and cobalt-oxide refinery in which arsenic trioxide was one of the by-products. Epidemiological evidence for an excess of lung cancer in the operations of this refinery was provided by the then Department of Health in 1958.[20] The refinery ceased operations in 1961. Because of the distribution of latent periods associated with lung cancer, compensable cases continue to appear in the population at risk. Two cases were compensated in 1974. In 1974, the first case of lung cancer attributed to an asbestos mine was compensated.[21] The person involved had had exposure in the asbestos mining industry in Quebec prior to working in Ontario.

By far the largest number of cases of lung cancer have been attributed to processes in nickel reduction plants. There have been ninety-eight of these, and a further thirty-nine cancers of the nasal cavities. Of the total of 137 cases, thirteen were compensated in 1974, and, among these, seven were cases of cancer of the nasal cavities. Compensation for the foregoing cases of cancer was initiated in response to epidemiological evidence reported by the staff of the Department of Health in 1958,[22] 1967,[23] and 1969.[24] All of the metallurgical processes to which the cases have been attributed were phased out of the operation in the period 1958 to 1962. Compensable cases, as indicated above, continue to appear in the popula-

TABLE 59

Historical record of cases of cancer compensated by the Workmen's Compensation Board and attributed to mines and related metallurgical plants (to November 1975)

	Number of cases of cancer			
Source of cases	Lung	Sinus	All	Remarks
Asbestos mines	1		1	Mine of last employment closed in 1974.
Nickel reduction plants[a]	98	39	137	Processes associated with cases ceased operation in the period 1958 to 1962.
Silver and cobalt oxide reduction plant[a]	22		22	Reduction plant ceased operation in 1961.
Uranium mines	18		18	For related study see Chapter 3.
Total	139	39	178	

a See subsection of this report on cancer of the respiratory system

tion of workers at risk. A recent major review of the medical and biological effects of nickel and its compounds contains a section on nickel carcinogenesis among workers in Wales, Canada, Norway, and Russia.[25] This section contains a concise summary of experience in Ontario. With respect to reduction plant operations in the Sudbury area it states:

> at the same smelter [referring to reference n.24] in Copper Cliff, during the years 1950–67, there was no excess mortality from respiratory cancer among workers in nickel-converter operations who were exposed to intermittent high concentrations of metallic dusts and sulfur dioxide. At two additional sintering plants in the Sudbury region, which are engaged in processing nickel sulfide ore, there have been no cases of cancer of the nasal cavities and only a few cases of lung cancer. At these two plants, sintering is performed at a lower temperature, and the product contains 18–22% sulfur.

Therefore it appears that the identified causes of cancer from nickel operations have been removed.

Of the operational sources of cancer identified to date in the mining industry, continuing risks, other than those generated by past exposures in operations now closed, certainly exist in the uranium mines and the asbestos mines. The problem in the uranium mines has been dealt with in chapter 3, and recommendations will be made for surveillance of workers in asbestos mines. However, it is natural that workers should be concerned that there may be as yet undetected consequences of past chronic and acute exposures in the industry.

The epidemiological studies by the Ministry of Health have contributed essential evidence for the protection and compensation of mine workers. It is regrettable that it has not been government policy to release these studies in full or in summary form upon their completion. Workers have an intrinsic right of access to information about the risks inherent in work. If society is not made aware of the consequence of risks at work, the government itself cannot render wise judgment on the acceptability of current risks. There have been too few epidemiological studies of workers in mines because resources for occupational health in the Ministry of Health have been woefully inadequate within a health-care system which spends massive sums on curative services but little on prevention. The Commission believes that resources for occupational health deserve a far higher priority than they have been given, and a basis for such a higher priority will be recommended in chapter 6. It is essential that significant health hazards be anticipated as well as responded to. The Commission here recommends:

That epidemiological reviews of selected populations subject to chronic exposure to toxic substances in reduction plants and mines matched to suitable control groups be conducted on a five-year cycle by or under the guidance of the Occupational Health and Safety Branch and that the essential results of such studies be summarized and published upon completion.

Certain suggestions for the subject of such studies are subsequently made. The Ministry of Health in its brief has outlined a number of important areas for work.

The Commission understands that the Ministry of Health has been receiving from the nickel-producing companies reports on deaths occurring among employees and pensioners and that these records are reviewed periodically. The Commission commends these procedures and will make a recommendation for the incorporation of such data on a selective basis in a central system of occupational health records. Further, the Commission notes that INCO Ltd and the United Steelworkers of America have recently entered into an agreement to establish under company funding a Joint Occupational Health Study Program, 'for the purpose of developing a better understanding of the working environment ... through independent industrial health surveys and research in connection with potential occupational illness and disease.[26] The Commission commends this new evidence of constructive co-operation between labour and management.

Among the toxic substances occurring in reduction plants, nickel carbonyl has attracted the particular concern of workers because of its extreme toxicity.[27] Reference has already been made to acute encounters with it. The concern here is with the possibility of it inducing cancer. There is some evidence that the inhalation of nickel carbonyl can produce cancer in rats[28] but the conclusiveness of this evidence has been questioned.[29] The Commission has found no conclusive epidemiological evidence in the literature that nickel carbonyl is or is not a carcinogen under the current conditions of human exposure. Sufficient time has not elapsed for there to be any epidemiological evidence from the new nickel refinery at Copper Cliff.

The following circumstantial evidence has been cited concerning cancer of the respiratory system in nickel refining in Wales.[30] In Wales, where nickel carbonyl has been a process product since 1902, an excess of cancer of the lung and nasal cavities was confirmed in epidemiological studies conducted in 1939, 1958, and 1970. The studies of 1958 and 1970 provided some evidence of the stages of the process to which the excess of cancer

could be attributed. The latest study states as follows: 'The epidemiological evidence in their reports (Morgan, 1958; Doll, 1958) strongly suggested that the risk was associated with the preliminary steps of the process preceding the formation of nickel carbonyl and that the risk has been eliminated from the industry by process changes in Britain by 1925.'[31] A further appreciation has been given in a recent report of the International Centre for Cancer Research at Lyon:

> Although the exact nature of the carcinogenic agent in nickel refining is unknown, the cancer hazard has been associated with the earliest stage of refining which involves heavy exposure to dust from relatively crude ore (Doll, et al., 1970). The view that nickel carbonyl is alone responsible has been discounted due to the disappearance of cancer risk despite continued use of the carbonyl process after 1925 in South Wales and due to the detection of an excess risk of respiratory cancer in refineries using the electrolytic and not the carbonyl process in Canada (Mastromatteo, 1967) and other countries.[32]

In the light of this evidence and as a means of ensuring the earliest possible detection of any health risks from nickel carbonyl, the Commission recommends:

That a nominal roll of workers at risk of exposure to nickel carbonyl in reduction plants and pilot plants be established by the Occupational Health and Safety Authority in co-operation with the industry and that the morbidity and the mortality experience of this nominal roll be reviewed at least every five years.

OTHER RESPIRATORY DISEASES

Asbestosis

Asbestos, which is distinctive by being separable into filaments, is both fibrogenic and carcinogenic when inhaled as dust in human populations.[33] A recent review by Health and Welfare Canada states that 'no concentration of asbestos can be specified at this time that affords no carcinogenic risk.'[34] As with ionizing radiation, the issue of standards is one of risk acceptance. Its fibrogenic effects are reflected in asbestosis, a form of lung disease characterized by a slowly progressive, pulmonary fibrosis whose stages can be identified by the radiographic methods used for detecting silicosis. The latent period for the development of asbestosis may be twenty or more years. Asbestos dust may also induce lung cancer and mesothelioma, a form of malignant tumour of the membrane that enfolds

the lungs or the abdominal cavity. The latent period for the development of mesothelioma may be over twenty-five years. The risks of cancer for asbestos workers who smoke cigarettes are many times greater than those for non-smokers.[35]

The asbestos mined in Ontario is of the chrysotile type. The mining operations have accounted for about 2 per cent of Canadian production of asbestos and about 0.4 per cent of employment in the mines in Ontario. The operations involve open pit extraction accompanied by mills. The first case of lung cancer to be charged to an Ontario asbestos mine was compensated in 1974 (see n.21). The first case of asbestosis to be charged to an Ontario asbestos mine was compensated in 1975.[36] There has been some production of asbestos in Ontario for over thirty years; the total employment in these operations was 225 in 1950, 254 in 1960, and 200 in 1970. Because of fluctuations in operations and short-term labour turnover it is difficult to know how many persons have been subject to exposure.

The Mines Engineering Branch has not issued any code of requirements for dust measurement in the asbestos mines, although written instructions have been issued from time to time by the engineers of the Branch. The Ministry of Health, at the request of the Mines Engineering Branch has periodically taken dust surveys. The voluntary system of dust measurement introduced by the Mines Accident Prevention Association in 1959 was not, and has not been, applicable to the asbestos mines (or to the salt mines).

After the Ministry of Natural Resources adopted the standard of 2 fibres per cubic centimetre of airborne dust in 1975, one mine closed down. A new mine whose mill began operating in 1976 was closed on an order of the Ministry of Natural Resources because of dust conditions in the mill; this operation is currently coming back into production.

The director of the Mines Engineering Branch has stated that workers in dust-exposed occupations in asbestos mines have not been exempted from the requirement for a Miner's Certificate under the Mining Act, so that standard radiographic chest records of the working population comparable to those for miners exposed to silica-laden dusts have been accumulated at the chest-examining stations of the Workmen's Compensation Board (and Ministry of Health).

The Commission believes that the small Ontario asbestos mining operations have not been subject to adequate review and recommends as follows with the intent of invoking the principles of recommendations already made with respect to silicosis and to lung cancer in the uranium mines:

That the appropriate substance or intent of recommendations 8, 9, 10, 39 (2), 40, 42, and 46 [as listed in appendix A] *be made applicable to asbestos mines and plants.*

These recommendations call for the application of codes of practice and schemes of practice for ventilation and dust control, for the engineering monitoring of dust and ventilation, for the specification of dust levels at which, first, corrective action must be taken and, second, closure of a workplace is required, for the sample monitoring of personal exposures and for smoking to cease among exposed workers.

To ensure the assessment of all available evidence of health impairment among the population that has been and is at risk, the Commission recommends:

That the Occupational Health and Safety Authority establish, with the co-operation of the Workmen's Compensation Board and the mining industry, a nominal roll of all persons who have worked one or more months in exposure to asbestos dust in the asbestos mines and plants;

That the Occupational Health and Safety Branch commission a review of the radiographic record and of the mortality experience for the asbestos nominal roll on a five-year cycle.

Since there is no clear evidence that a threshold level of asbestos dust exists below which there is no risk of cancer, the Commission does not, for the reasons cited in chapter 3 on lung cancer and ionizing radiation, recommend work adjustment procedures that would lead to an increase in the total population at risk. However, if the risks of disabling asbestosis arising from the fibrogenic property of asbestos dust in mining populations can be shown to be very much greater than the risk of malignant tumours, then a work adjustment policy similar to that outlined for silicotics in recommendations 21, 24, 25, 26, 27, and 30 may be worthy of consideration. The Commission's endorsement of a work adjustment policy for silicotics in uranium mines is based on the evidence that the risk of silicosis is much higher than the risk of attributable lung cancer. With asbestos dust, as with ionizing radiation, the essential need is to minimize exposure by the rigorous control of the carcinogen.

The evidence through 1975, namely, one case of lung cancer and one case of asbestosis, both compensated in persons at or past retirement age,

one of whom had a significant part of his exposure to asbestos outside the province, is too slim to be indicative of the future development of cases in the mines in Ontario.

Chronic bronchitis

Of the lower respiratory tract diseases, none affects more workers than chronic bronchitis, an inflammatory condition of the bronchi which in a chronic state may be defined as the presence of a cough productive of phlegm on most days for a period of one year or longer (see n.46). Emphysema, which may be associated with chronic bronchitis, involves an anatomical change in the lungs characterized by enlargement of the air spaces beyond the small bronchioles with destruction of the air sac walls and by shortness of breath.[37] The labour unions have stated their concern that much of the prevalence of chronic bronchitis and related obstructive lung disease may be attributable to exposure to airborne contaminants.

Chronic bronchitis is not recognized by the Workmen's Compensation Board as being an industrial disease under the definition of the Act. The Commission's understanding of the Board's policy is as follows: if a person has an industrial disease such as silicosis or asbestosis and the condition is aggravated by the presence of other disease conditions such as chronic bronchitis, the Board may increase the level of disability assigned for purposes of determining the amount of wage compensation. Further, if there is clear evidence that chronic bronchitis or emphysema existed prior to employment in work involving prolonged exposure to irritants such as welding fumes, sulphur dioxide, acid fumes, and so on, and the work has induced periodic aggravation of the pre-existing condition, the Board may consider a claim on the basis of aggravation. Finally, if the onset of chronic bronchitis can be traced to a single acute exposure to a respiratory irritant the Board may allow a claim. The Board does not allow claims based simply on extended encounter at work with airborne toxic substances where there is no specific ground for attributing to such exposure the condition of chronic bronchitis on which the claim is based. As with lung cancer in the uranium mines, the Board might allow a larger number of claims if there were sound epidemiological evidence for an excess of the disease over that which is to be expected in appropriate comparison populations.

The epidemiological evidence related to the exposure of Ontario mine workers to sulphur dioxide and metal dust and fumes, and to mineral dusts and diesel fumes, will now be briefly reviewed. The levels of dust exposure underground were reviewed in chapter 2. Table 60 provides representative

TABLE 60

Dust conditions at selected surface operations for certain metal types (average for surveys of 1974 and 1975)

Metal type	Secondary crushing	Dry mills and processing	Wet mills and processing	Smelters	Refineries	Iron ore plants	Shops and surface
Nickel	389	142[a]	278	282	117	278[b]	231
Iron	467	834	439	–	–	506	291
Uranium	205	–	138	–	–	–	153
Gold	239	88[c]	144	108[c]	–	–	141

NOTE: Measurements by standard konimeter practice (in particles per cubic centimetre)
a Two sets of measurements: 3 and 9, 1975
b Three sets of measurements: 3 and 9, 1974 and 9, 1975
c Three sets of measurements: 9, 1974 and 3 and 9, 1975
SOURCE: Mines Accident Prevention Association Semi-Annual Surveys.

average dust measurements by konimeter in surface reduction plants. The higher dust levels are in iron plants and nickel plants.[38]

Following the identification of an excess of lung and nasal cancer in a Copper Cliff sinter plant in 1969, the then Ontario Department of Health, in co-operation with the nickel producer, conducted a comparative study of the morbidity and mortality experience of samples of workers in a mine and in three distinctive sections of operations in a reduction plant located at Copper Cliff. This study indicated that

> for lower Respiratory Diseases there was a statistically significant increase in reported absences [from work] among the Converter men ... Most of the excess occurred in men with 25 years or more of service ... The average duration of Lower Respiratory Disease absences in the Converter men was essentially equivalent to that expected. The findings suggest that employment for 20 years or more in the Converter department is associated with an increase in the frequency of lower respiratory diseases, but without any increase in severity.[39]

From the four types of work locations studied the converter area was selected to entail distinctive exposure to sulphur dioxide, metal fume and dust. A follow-up report by the Ministry of Health has recently been completed.[40] In this report the prevalence of chronic bronchitis, as determined subjectively through a standard questionnaire, is indicated to be 1 in 4.4 among 310 converter workers and 1 in 12.8 among the 64 refinery workers used as a comparison group. The prevalence of chronic bronchitis among Ottawa males in the ages 25 to 64 is about 1 in 12.[41] The foregoing difference between the prevalence for converter workers and that for refinery workers is stated to be statistically significant. Lung function tests (see explanation in n. 40) also revealed statistically significant differences between converter workers and refinery workers. For both, the symptoms of chronic bronchitis occurred almost entirely among smokers and former smokers. Measurements at fixed locations for total dust and for sulphur dioxide, averaged over a shift and the locations, indicated a mean value of about 2.4 milligrams per cubic metre of total dust and about 2.5 parts per million of sulphur dioxide. The current TLV for sulphur dioxide is 5 parts per million. The appropriate TLV for the dust depends on the chemical analysis. A value of 7.5 mg/m^3 has been set for another smelter. These data for Ontario are comparable to recent results for workers in a US copper smelter.[42] There is contrary evidence for the effects of a combination of sulphur dioxide and dust when studied among workers in all departments in two British steel works.[43]

Evidence of this kind raises questions about the adequacy of control of

exposure to toxic substances, the appropriateness of current TLVS,[44] and the legitimacy of compensation. Regarding the latter the Commission recommends:

That workers in reduction plants who have been exposed for twenty years or longer to sulphur dioxide at levels approaching the current Threshold Limit Value and to associated dust and fumes, and who exhibit the clinical diagnosis of chronic bronchitis and impaired pulmonary function as identified by objective tests, be considered for compensation at up to a maximum of 20 per cent disability.

The Commission recognizes that, to use the words of Gilson, 'in the individual it is very rarely possible to apportion, even approximately, the contribution of each of the many factors responsible for the severity of occupational bronchitis or the altered lung function.'[45] As with lung cancer among uranium miners, this fact begs the question of how compensation might be made.

When there is obtained in Ontario statistically significant evidence of an excess of chronic bronchitis in a particular subpopulation of Ontario mine workers compared to an appropriate control group of Ontario mine workers, the Commission believes the Board should consider the compensation in keeping with the nature of the evidence as it becomes available and is altered by planned epidemiological reviews. In the absence of knowledge that would allow the clear attribution of individual cases, it is necessary to establish an arbitrary basis for compensation the motivation of which is to render to the workers as a whole a measure of rough justice. The recommendation made is of this character and the limit of 20 per cent disability is related to the character of the disease. The toxic substances encountered at the workplace may be considered to be the ultimate involuntary aggravating factor in the disease. Individual compensation in such circumstances is not based on scientific knowledge other than epidemiology but on public policy. The alternative of a 'hazard' increment in wages for the group at excess risk is in the Commission's view less defensible. The essential need is to reduce the exposure of the workers to the aggravating contaminants.

Concerning a possible relation between chronic bronchitis and mineral dust (with diesel fumes as an added factor for some subpopulations) there is some evidence from the Elliot Lake uranium mines. The study of underground and surface workers conducted by the Ministry of Health in 1974 revealed the following.[46] In the study population of 707 persons who worked underground, one in 7.6 reported symptoms of chronic bronchitis,

while the prevalence among the remaining population of 266 who worked in dusty surface and mixed surface dust and underground exposure was one in 9.2. The prevalence for all workers as a group was one in 8.3. The differences between these groups is not large and is not notably higher than the prevalence of chronic bronchitis among Ottawa males in the age group 25 to 64. Statistical analysis of both chronic bronchitis and of lung function parameters indicated that the occupational environment plays some role.[47] The dominant factor was smoking. Over a wide range of ages the prevalence among smokers was about three times that among non-smokers. The prevalence in both groups increased with age by several times. There is strong evidence, therefore, that the prevalence of chronic bronchitis among all mine workers could be reduced by a large factor if cigarette smoking ceased. The Commission's recommendation to uranium miners to cease smoking to lower risks of lung cancer applies with equal force to all workers to lower risks of chronic bronchitis.

Although the separate effects of mine contaminants, smoking, city air pollution, and socioeconomic factors on the prevalence of chronic bronchitis among hard rock miners are not clearly established, there is persistent evidence from other jurisdictions that miners exposed to dusts have more respiratory disability than the comparison groups used and that the effects are related to dose. The differences are about twofold.[48]

There is need for more extensive epidemiological research on the prevalence of chronic bronchitis in Ontario mines and plants. It is suggested that a major study of dust-exposed underground workers, dust-exposed surface workers, and non-dust-exposed surface workers be undertaken and that smokers and non-smokers be examined in each group. The Elliot Lake review did not permit a clear separation of these groups. Further, the prevalence of chronic bronchitis among subpopulations of workers in the iron reduction plants and other nickel smelters should be compared with that in suitably matched control groups. In the event that such epidemiological studies, suitably matched between comparative populations of underground, reduction plant, and surface workers, reveal a statistically significant excess of chronic bronchitis in Ontario mines and plants, the Commission would recommend that the provisions of the recommendation relating to sulphur dioxide, metal fumes, and dust be extended to the workers among whom the excess occurs. Underground mine workers in South Africa are currently compensated for obstructive lung disease in the absence of silicosis.[49]

Diesel fumes are one of the possible factors in the induction of chronic respiratory disease whose role requires elucidation. The recent study of

respiratory conditions among workers in the uranium miners where some are exposed to diesel fumes and some are not observes:

The total number of persons with chronic bronchitis was not large in relation to the number of men in the study [118 out of 973]. Moreover, on dividing these into subgroups the small numbers make valid judgements difficult. Despite these considerations and after having made allowance for age and smoking habits, there was no evidence from the available data to indicate that the use of diesel powered equipment at Denison Mine has an identifiable adverse effect.[50]

The Commission is aware of little epidemiological evidence dealing directly with the effects of diesel fumes on the mortality of miners.[51] One recent US study of mortality experience among mine and mill workers in eight potash mines, two of which have used diesel engines as the major energy source for underground transportation,[52] gives the following appreciation:

To explore the possibility of effects of exposure to diesel exhaust on mortality, the underground potash cohort was subdivided on the basis of which men had worked (and when) in these two mines and the life table method was again used to determine expected deaths. There were 31 deaths in 6733 person years. Except for violent deaths, no major cause of death exceeded expectation among men who worked in the diesel mines. No causes of death were significantly different between miners who worked in dieselized mines and those who worked in other mines. It may be noteworthy that the 'other respiratory disease' category which was high among underground workers was not different between diesel and non-diesel workers. However, there may have been insufficient elapsed time since the start of diesel usage for chronic or long latent period diseases, such as emphysema and lung cancer, to be manifested as excess deaths in the relatively small exposed group.

There is a need for further epidemiological review of possible effects from the use of diesel engines, which came into use in Ontario about 1950 and are now widely used. The Commission urges that such a study be included among the epidemiological reviews that the Occupational Health and Safety Branch conduct or have conducted.[53]

Under Section 213(9) of the Mining Act, internal combustion engines may not be used underground without permission in writing from the chief engineer of the Mines Engineering Branch. Gasoline-burning engines have never been permitted, but equipment driven by diesel engines has been approved on a unit-by-unit basis, provided that each unit and the conditions surrounding its use satisfy a Code of Requirement the current version of which was issued in 1973.[54] This code specifies the maximum permis-

sible levels of aldehydes, carbon dioxide, carbon monoxide, and nitrogen dioxide in the atmosphere adjacent to the engine. It also specifies the minimum amount of ventilating air required and the maximum sulphur content of the fuel oil and sets out certain general requirements related to fuelling, exhaust scrubbing, operating, maintenance, and record-keeping.

Complaints from the labour unions have centred on alleged defects of maintenance both of the diesel engines themselves and of the equipment driven by them and upon alleged excesses of diesel fume contaminants in air breathed in the presence of the equipment.

While diesel equipment has been introduced with considered care into Ontario mines, the Commission believes that there are instances in which maintenance is inadequate and in which more equipment than is proper becomes concentrated in particular work locations. Diesel control maps which clearly specify zones of operation should be well understood by supervisors, operators, workers, and worker-auditors. To ensure strong emphasis on the basic problems of the use of diesel engines, the Commission recommends:

That the Occupational Health and Safety Authority, in co-operation with the industry and labour, prepare a code of requirements for diesel emissions;

That the Mines Inspection Branch prepare a code of practice for the provision of ventilation and for the fuelling, operation, and maintenance of diesel engines;

That each mine using diesel equipment be required to file with the Mines Inspection Branch a scheme of practice for the short-term and long-term maintenance of its diesel engines.

The first two recommendations in effect split the existing diesel code into two parts each of which the Commission believes requires elaboration. The final recommendation is for a Scheme of Practice, which should set out the practices for staging, carrying out, and verifying the state of maintenance of diesel engines. There has been a substantial co-operative Canadian research programme related to the latter problem.[55]

Diesel exhausts contain an extremely complex combination of gases, vapours, and particulates the toxic effects of all components of which are not fully understood.[56] While the Commission has found no epidemiological evidence that diesel fumes are contributing to chronic disease in mine

workers, there has been little research directed to finding out. The Commission has recommended that such research be conducted by the Occupational Health and Safety Branch, and further urges that animal experiments be conducted to determine the toxic effects of diesel particulates. The following toxicological assessment of diesel exhausts has been given:

> Toxicologic evaluation of the numerous components of diesel exhausts and their probable interactions points to oxides of nitrogen and the oxides of carbon as substances posing the greatest threat to health. Smoke, with its adsorbed, partly oxidized, and nitrated hydrocarbons, chiefly aldehydes and nitroparaffins, although constituting an irritation and odor problem, actually can contribute to health effects by carrying the irritants to the deeper, more sensitive recesses of the lung, where they can act to initiate, promote, or accelerate emphysematous, fibrotic, or carcinogenic processes. Smoke-adsorbed oxides of nitrogen would be particularly notable in this respect.
>
> Serious major gaps in analytic information still have to be filled before a firm toxicologic appraisal can be made, however. Information is needed, among other things, on the types and amounts of aldehydes, particularly unsaturated aldehydes, whether smoke-adsorbed or free, and whether, and under what conditions polycyclic aromatic hydrocarbons of the carcinogenic type are smoke-adsorbed.
>
> From the toxicologic viewpoint, two things can be said with assurance: (1) poorly maintained diesel engines will enhance to such proportions all of those constituents most hazardous to health and comfort as to require uneconomic amounts of ventilation to reduce their levels to acceptable concentrations, and (2) underground mine temperatures must be maintained below 80°F if greatly enhanced toxicity from unburned hydrocarbons is to be prevented.[57]

There is a widely held view in the industry that under current conditions of operation of diesel engines in underground mines in Ontario the toxic substances other than those for which standards have been set are not present in sufficient quantities to constitute a significant risk to health.

HEARING LOSS AND INDUSTRIAL NOISE

Noise as unwanted sound is familiar to everyone who enjoys the normal sense of hearing. Noise-induced hearing loss results from exposure to high levels of noise over a prolonged period of time.[58] The onset is slow, affecting both ears, and the person is usually unaware of its progression until the point is reached where it interferes with conversation. It results from irreversible physical damage to the tiny hair cells located in the inner ear produced by intense acoustical pressure waves in the ear canal. The evidence for this form of sensorineural deafness among mine workers will

TABLE 61

Permanent disability awards at latest settlement for hearing loss in the mining industry to 31 December 1974

First permanent disability award in period	Awards		Mean Percentage of permanent disability at latest settlement
	N	%	
1950–4	1	0.2	10.0
1955–9	4	0.6	5.1
1960–4	7	1.1	6.2
1965–9	69	11.1	8.4
1970–4	540[a]	87.0	8.3
Total	621	100.0	8.3
Standard deviation			5.9

NOTE: The 621 cases of permanent disability settled as of 31 December 1974 are distributed by the calendar period in which a permanent disability award was first made to each of the persons involved.
a Of these awards, 213 were first made in 1974
SOURCE: *Claims for Industrial Noise Deafness*, Mining Industry of Ontario, 31 December 1974, W.C. Wheeler, Workmen's Compensation Board, 5 April 1976

be examined.[59] It is a wholly preventable but incurable disease the consequences of which among persons such as metal smiths, weavers, and boilermakers have been recognized for centuries.

A worker who becomes partially deaf from noise attributable to work or other causes may suffer several handicaps. For example, he may be refused promotion to a job as a cage tender or a hoistman who is required to respond accurately to auditory signals. His ability to converse at work and at home may be impaired. High noise levels may affect him psychologically by causing irritability, mental fatigue, and lessened attention and alertness, which may lead to accidents. Society is much less sensitive to a deaf person than to a blind person.

THE RECORD OF HEARING LOSS

Industrial noise deafness was first recognized as a compensable injury as the result of a court decision in New York State in 1944. In Ontario it became compensable on 31 March 1947, when the definition of industrial disease in the Workmen's Compensation Act was generalized as in Section 1(*l*).

More than one third of all claims for hearing loss received by the Board in the decade 1965–74 were from the mining industry.[60] Table 61 shows the burst of permanent disability awards in the past decade. Almost 90 per cent of all permanent disability awards settled to the end of 1974 were awarded in the five-year period 1970–4. The cumulative direct costs to the end of 1974 for all permanent disability payments to the 621 persons involved has been about $3 million, or about $5,000 per disability. These costs include capitalization for pensions. Associated with the 621 permanent disability settlements in Table 61, there were 338 medical aid cases and 168 rejected claims among all the claims that had been adjudicated and settled to the end of 1974. Medical aid cases are now those in which the Board pays for the worker the authorized costs of specialized medical consultations about his hearing.

The evidence is clear that cases of hearing loss in the mining industry are now being recognized in massive proportions. For reasons related to changes in administrative practice for compensation, which will subsequently be explained, a significant number of these cases can be regarded as a backlog of pre-existing injury. This fact does not alter the reality that men in large numbers have experienced significant loss of hearing in the mines. Continuing evidence of this fact can be expected until current hearing conservation programmes prove their effectiveness. The percentage permanent disability figure in Table 61 is the percentage of eligible earnings provided to the worker as a pension. The eligible earnings at present are 75 per cent of current wages up to a maximum rate of $15,000 per annum.[61] The disability currently allowed for the complete loss of hearing in both ears is 30 per cent.[62]

To determine how the cases of hearing loss are related to the populations in the various classes of mines the distribution of adjudicated claims was examined. Table 62 reveals two major anomalies. The first is that hearing-loss claims in the iron mines, which are largely open pit, are very much less than expected on the basis of the proportion of the mining population involved. This evidence suggests that the cumulative noise exposure in such operations has been much lower on the average than in underground mines. The second is that claims among shaft sinkers are very much higher than expected. The latter evidence has been checked by consulting company records of the Workmen's Compensation Board. The estimate is, if anything, conservative, and is a sad commentary on past conditions of ear protection among such workers where the higher levels of noise due to drilling are persistent (see Table 63).

An examination of the occupational histories of a 10 per cent sample of

TABLE 62

Distribution of adjudicated claims for hearing loss in the mining industry by type of operation

Type of operation	Claims observed (%)	Claims expected[a] (%)
Diamond Drilling	1.1	1.8
Gold	29.8	26.0
Iron	1.1	5.4
Nickel-Copper	48.0	49.0
Shaft Sinking	5.6	1.8
Uranium	5.3[b]	11.5
All Other	7.8[c]	4.5

a Expected on the basis of the employment in the designated type of operation averaged over the decade 1955–64. This choice is based on evidence that the majority of allowed claims are associated with persons with fifteen years or more of employment in Ontario up to the year in which their claim is first allowed.

b The very rapid diffusion of the uranium mining population after 1960 probably contributes to an under-ascertainment of claims attributable to exposure in these mines because the compensation is prorated between the mine of last employment and the pooled second injury fund (see Brief 136, 89).

c These are mainly the smaller mines for asbestos, magnesium, nepheline syenite, quartz, silver, and talc.

SOURCE: See Table 61

all the foregoing cases for which miner's certificate numbers are known was conducted for the Commission by the Board. This study showed that for approximately 90 per cent the principal employment was underground and that about 90 per cent had mine employment in Ontario for fifteen or more years at the time of the first allowance of a claim. Figure 19 shows the age distribution of the 760 claims first allowed in the period 1970–4.[63] The mean of the distribution is 56 years, but a significant number of persons experience compensable hearing loss between the ages of 40 and 50 and therefore carry a hearing disability as many as 25 years of their working life. A person entering mining at 25 years of age would be 40 after an elapsed time of fifteen years, which is a sample estimate of the average duration of mine employment in Ontario for persons with hearing loss.

NOISE AND THE RESPONSIBILITY-SYSTEM

For centuries men in certain occupations and their communities have

TABLE 63

Typical high noise levels in mines and plants near types of equipment designated

Location	Noise level in dB(A)
Underground	
Crusher	110
Fans	107–110[a]
Drills	115–125
Scraper	115
Open pit	
Drills	100
Tractor (in cab)	108
Truck (in cab)	95
Surface	
Ball Mills	103
Cone Crushers	103
Copper Refinery, Vertical Furnace	102-110[b]
Pellet Rolls	102
Rod Mills	96

a See US Department of the Interior, *Hearing Conservation for the Mineral Industry*, Bureau of Mines Information Circular IC 8564, 13.
b Ministry of Health survey of furnace operation
SOURCE: MAPAO surveys except as noted

simply accepted the fact that some persons became prematurely deaf. Despite the fact that industrial deafness became a compensable injury in Ontario in 1947, it was not recognized as a real problem in the mining industry until after 1960. The following quotations from mine managers at the hearings of the Commission indicate the nature of the situation from which current deafness injuries have arisen: 'Prior to 1956 no serious attempts were made to design noise out of mining, or to protect employees from existing noise ... some workmen, particularly drillers, used a shredded cotton waste, absorbent cotton or toilet tissue as a makeshift ear stopple.'[64] 'I am talking about '60, '61 and '62 when nobody worried about noise, it was just part of the job, the fact that your ears rang when you came off the shift was part of the job.'[65] The period during which the mining industry became alerted to noise as a problem corresponded to that during which a quantitative understanding of damage-risk criteria was being clearly established.[66] It has been a slow process to reach the state of concern, knowledge, and practice that exists now as the injuries to hearing induced in the past are being recognized in disturbing numbers. Among the

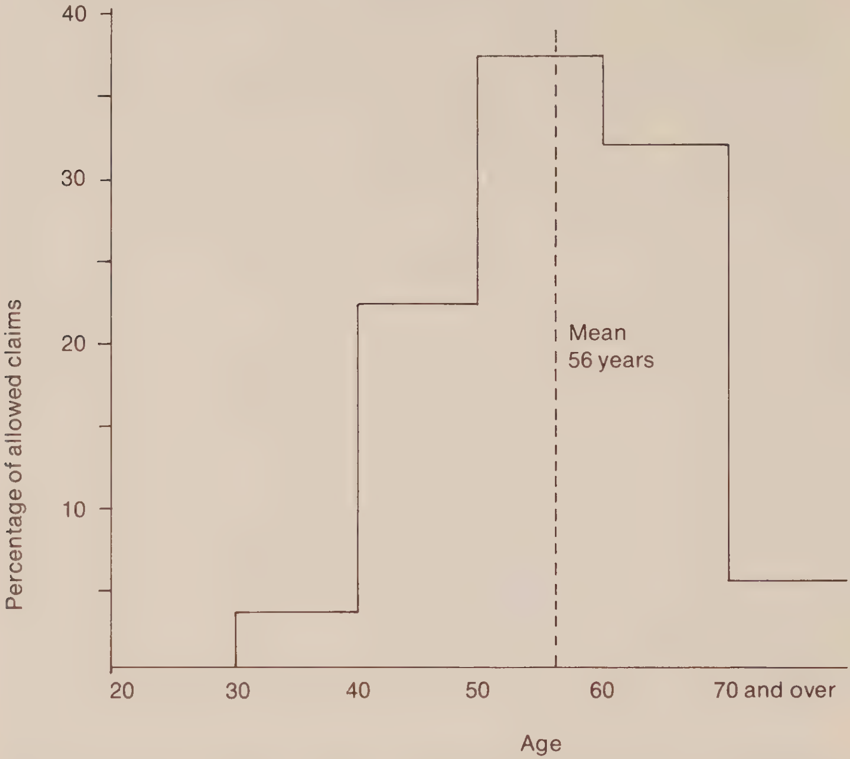


FIGURE 19 Age distribution of claims for hearing loss first allowed in the period 1970–4 (Note: total number of claims was 760, consisting of medical aid and permanent disability; Source: Table 61)

causes of injury to workers, noise is unusual in that it can be readily measured and the effects it produces on hearing can, in the absence of complicating disease and traumatic injury, be measured with some accuracy.[67] The first exploratory noise survey was taken in the mining industry by a large company about 1955. Formal noise surveys began in this company in 1966. The MAPAO conducted initial noise surveys and prepared noise report forms in 1968. It published a booklet on survey procedures[68] in 1973 and has carried out noise surveys for many mines.[69] At the present time, 'noise maps' are available in most of the operations in the mining industry so that noise conditions have now become reasonably well defined.

What have been the acceptable levels of noise and what levels actually

occur? While the Mining Act has provided for management to designate areas for the wearing of approved hearing protective equipment,[70] no codes of practice regarding the use of such equipment have been issued. A code of requirement with respect to allowable levels of exposure to noise was first issued in July 1974.[71] For a duration per day of eight hours the maximum allowable noise level at the ears is 90 decibels [dB(A)] and no exposure in excess of 115 decibels is permitted (see n.67 for a definition of dB(A)). In a noise level of 90 decibels it is difficult to sustain communication with another person by shouting from a distance of about one foot (mouth to ear).[72] The current (1975) TLV of the American Conference of Governmental Industrial Hygienists is 85 decibels for eight hours. The MAPAO currently recommends that all areas having an 85-decibel noise level or higher be mapped as a hazardous zone.

Noise levels near operating stationary equipment such as fans and drills in mines or crushers and rod mills in plants are relatively stable. Moving equipment such as load-haul-dump machines or trucks alter local noise levels, and persons riding on vehicles experience a varied noise environment usually dominated by the machine they operate. Typical high noise levels in mines and plants measured at operator positions or near the equipment when in full operation are listed in Table 63.[73] The evidence is unequivocal that existing noise levels in mining operations can induce serious loss of hearing among workers. As the technological scale of mining operations has grown so has the potential noise hazard. Noise is therefore a continuing serious hazard to the well-being of mine workers demanding hearing conservation programmes of high effectiveness. Such programmes involve four elements: 1/ the assessment of noise levels and profiles of encounter with noise, 2/ the control of noise sources and of noise exposure, 3/ the monitoring of noise exposure and the screening of the hearing of workers, and 4/ the provision of workmen's compensation and work adjustment. The purpose of each of these elements needs to be made clear.

With respect to the assessment of noise levels and profiles of noise encounter it is essential that mining operations maintain noise maps and develop fuller knowledge of profiles of noise encounter. The Commission recommends:

That each mining operation maintain noise maps based on full-scale conditions of operation which delineate all areas of work at which the noise level is 85 dB(A) or higher.

Many companies are now doing this. Workers, worker-auditors, and the joint health and safety committee should have access to these maps.

Instrument technology exists to determine cumulative effective noise exposure over a working shift. The Commission recommends:

That the mining industry, in co-operation with labour and the Occupational Health and Safety Authority, have conducted research to determine shift-profiles of noise encounter for representative occupations in mines and plants both in the absence and in the presence of actual and best-available hearing protection, that such profiles be codified and published, and that a code be assigned to each worker who regularly encounters areas of work in which noise levels of 85 dB(A) or higher exist.

Codification of characteristic profiles of noise encounter can provide a basis for specifying the nature of a worker's exposure to noise and provide an important element in audiometric records.

Exposure to noise can be decreased by reducing its generation and propagation through the air, and by providing isolation of the ears from the onslaught of incident sound waves. Drills are the source of the worst noise, and substantial research has been directed at reducing it.[74] However there has been little evidence of a concerted effort on the part of the mining industry to establish, in co-operation with equipment manufacturers, labour, and government, expected standards of noise generation for mining equipment as a whole.[75] A manager of one of the smaller mines made the following observation to the Commission: 'Even though we want mufflers on our machines there is very little we can do about it ... We are at the mercy of the manufacturers to a large extent.'[76]

The Commission, believing that the basic responsibility for equipment standards rests with the industry and manufacturers, recommends:

That the mining industry and equipment manufacturers, with the Canadian Standards Association, expedite the development of standards for the assessment of noise from mining equipment, and for the performance of personal safety equipment and cab enclosures in attenuating noise, and that such standards be invoked by the industry in specifying noise performance requirements for new equipment.

The industry is aware that feasible technology is available to reduce noise from many kinds of machines not only in primary design but also in installation through the use of isolation. Mufflers are specified by many companies where they are available. Underground fans, for example, can be effectively silenced: the Commission visited a mine in Sweden where all fans had been silenced. Need for ready access for maintenance may pose

difficulties in noise reduction. The MAPAO has an important role to play in compiling design criteria and case-study illustrations of good practice. The Commission understands that this is being done and recommends that such information be available to joint health and safety committees. In any event, it is unreasonable to expect the worker to bear the full burden of excess noise by being compelled unnecessarily to wear ear plugs and muffs which may be uncomfortable and irritating.[77] Ear plugs and muffs add to the total kit of personal 'enclosure,' a kit which in its current form leads more than a few workers to avoid its meticulous use. The following frank statement by a mine manager defines what needs to be done in the design of personal equipment:

> You will notice in the last safety report that I received from the safety supervisor, I think of the 12 work crews he saw 8 were not wearing eye protection but were wearing ear muffs. When I was Chairman of the Safety Sub-Committee of the MAPAO we actively tried to get manufacturers to develop a helmet that would incorporate hearing protection, head protection and eye protection, all in one unit ... I believe that the present hard hat, with the add-ons (ear muffs and glasses), it is not proper protection and I believe the problem here, we are at the mercy of suppliers who say, well if you put out $50,000.00 on the table we will turn around and do some research and development.[78]

The recently formed Mining Industry Research Organization of Canada has indicated that research on a protective helmet represents one of its priorities. The Commission simply observes that the record of eye, ear, and head injuries provides an absolute minimum index for determining the investment that is justified to achieve improved environmental protection of workers through personal equipment and zonal enclosures, such as rugged, ventilated, and sound-proofed cabs, which deserve wide application for heavy equipment. However, until technology is available that will properly replace or avoid the need for effective ear plugs and muffs, it is crucial that management provide them and that workers meticulously wear them to preserve their hearing. One of the important issues to be considered in the wearing of protective devices is the worker's ability to discriminate warning signals from noise. The Commission recommends:

That the Occupational Health and Safety Authority issue a code of practice for the selection and use of personal ear protection and for communicating in the presence of noise.

The Commission urges labour and management to co-operate in achieving a thorough discipline in this matter and urges the Joint Health and Safety

Committees to review the underlying issues of policy and achievement.

Of all the elements of an effective hearing conservation programme, none is more important than the screening of the state of hearing of the workers. Among the questions requiring a clear answer are the following. What are the goals of screening and who is to be responsible for it? Both the MAPAO and the unions have expressed a desire that audiometric screening be undertaken at the chest examining stations that provide the X-ray examinations required under the Mining Act for the validation of a miner's Certificate. The Commission has expressed the view that these stations should be capable of carrying out lung function and audiometric testing in support of research based on sample populations to be undertaken by or under the auspices of the Occupational Health and Safety Authority. However the Commission does not believe that these stations should be responsible for maintaining massive audiometric records of large populations of workers. The Commission recommends:

That, by statute, each mining company be made responsible for maintaining effective audiometric records for each employee who in the absence of hearing protection encounters noise at levels of 85 dB(A) or higher and that such audiometric records be required to be keyed 1/ to social insurance numbers, 2/ to Miner's Certificate numbers where such have been assigned, and 3/ to a code number of noise-profile-encounter as previously recommended.

It is important that the audiometric record for an employee as maintained by a Company be complete and include data acquired by specialist review as well as by regular audiometric testing and that these records be preserved after an employee leaves employment. Further, the Commission recommends:

That the Occupational Health and Safety Branch commission on a five-year cycle statistical assessments of the state of hearing among sample populations of workers in mines, and that the first review be of production crews in underground operations, including diesel operators.

The Commission also suggests that research be conducted to determine if the accident experience of workers with loss of hearing differs significantly from that of other workers.

Audiometric records should be effective in detecting abnormalities of hearing for the purposes of 1/ referral for medical review to confirm the nature of any hearing handicap and to provide counsel on conditions of

continuing employment, 2/ providing evidence related to any claim for compensation, 3/ checking the effectiveness of the company's hearing conservation programme and the participation of the employee in that programme, and 4/ providing data for a statistical perspective on the state of hearing among populations of workers. The technical requirements for an occupational audiometric testing programme have recently been outlined.[79] The Commission endorses these general requirements and recommends in addition:

That the Occupational Health and Safety Branch regularly inspect all audiometric testing facilities not under the supervision of a designated medical specialist, and that any designated medical specialist be required to certify biennially in writing that the facilities under his supervision conform to the minimum standards of the Ministry of Health as then current.

Smaller companies may wish to band together as in Sweden to establish or gain access to an authorized and supervised audiometric testing facility.

The Ministry of Health guidelines call for screening at the time of employment, at least annually thereafter for persons who work in areas where noise levels are in excess of 100 decibels, and every three years for those in areas where noise levels are less than 90 decibels. The foregoing guidelines also call for the referral to a physician of any employee with hearing loss in both ears who exhibits an increase in hearing threshold[80] in the better ear averaging 26 decibels or over at pure tone frequencies of 500, 1000, 2000, and 3000 cycles per second. At this level an employee is entitled to reimbursement by the Workmen's Compensation Board for the cost of a specialist's consultation fee. Under current administrative practice of the Board, an employee whose average increase in hearing threshold at the foregoing frequencies is 35 decibels or more in the better ear is entitled to a permanent disability award if the changes can be verified as having an occupational cause and he is under sixty years of age.[81] The Commission sees no reason why a worker should not be shown his audiometric test record; it represents, after all, measurements on his person.

Compensation for hearing loss, although related to complex technical and medical characteristics of the auditory sense, is in the end based on social judgment rather than definitive scientific knowledge. Social judgment of what constitutes fair compensation has changed remarkably since 1947. The Commission understands that when hearing loss was first compensated in Ontario a person was not eligible for a pension until six months after *retirement*. Until the end of 1973, a person could not receive a pension

for which his state of hearing made him eligible until he removed himself from work in noise exposure, and no special programme of rehabilitation was offered to assist him. As of 1 January 1974 the Workmen's Compensation Act was modified to make administrative practice for industrial disease the same as that for an injury due to an accident. Persons with hearing loss became eligible on that date for disability awards while continuing to work in noise exposure. This fact has contributed to the recent burst of disability awards, because there was a backlog of persons with hearing loss who had not elected to leave their work with its noise exposure as a precondition for the receipt of a disability award. Further, the onus has been on the worker to see that a claim for compensation is initiated. While the workmen clearly must participate in the act of making a claim, the Commission believes that a fundamental professional responsibility rests on all those who generate and review audiometric records to advise and assist a workman to make a claim the compensability of which must be judged by the Workmen's Compensation Board.

The Commission asks why a person who loses the sight of both eyes is compensated at 100 per cent of eligible earnings while a person who suffers complete sensorineural deafness in both ears from industrial noise is compensated at only 30 per cent. Deafness isolates a person far more from social intercourse than does blindness, although in our technological society a deaf person can work at tasks unsuited to a blind person. Workmen's compensation is designed to sustain remuneration and does not attempt to measure the intangibles of social deprivation in conversation, unrealized advancement in job status, and many other facets of life. The Board has supported research on the assessment of the human impact of loss of hearing, and the Commission believes such work should include a study of job accessibility for persons with industrial noise deafness within and between companies, so that the effective economic impact can be more fully assessed. It is the Commission's understanding that since the last employer is charged only a prorated amount of the disability payments for the hearing loss of a current employee, there is no intrinsic economic impediment to the mobility of a worker with hearing loss. This point should be verified. It has been proposed that the Occupational Health and Safety Branch conduct research on the relationships, if any, between hearing loss and accidents among mine workers. Should a significant connection be established, the Board should consider a work adjustment policy for persons with hearing loss.

Loss of hearing from industrial noise is wholly preventable and incurable. Its incidence can in time be reduced to a small fraction of its current level if all parties, and not least workers, follow good practices with

diligence and care. Progress in eradicating industrial noise deafness will depend strongly on the keeping and analysis of effective occupational records. Questions of standards of exposure, medical surveillance, and occupational records have recurred through this report. Specific recommendations have been made concerning medical surveillance. The following notes are intended to summarize the issues related to standards and occupational health records.

ENVIRONMENTAL STANDARDS, HEALTH RECORDS, AND RESEARCH

The Commission has noted that with respect to toxic substances and physical agents such as noise, there are two kinds of standards for which monitoring is necessary: engineering standards governing technical conditions of operations in mines and plants, and standards for exposure of persons, such as TLVs. It has been recommended that a statutory standard for personal exposure to silica-laden dust and to ionizing radiation in the uranium mines be established on a basis that includes evidence from Ontario conditions. It is essential that there be guidelines for a large range of other toxic substances and physical agents and that all parties understand what these are. The Commission recommends:

That the Occupational Health and Safety Authority be assigned by statute the responsibility to establish standards or guidelines for personal exposure to all toxic substances and hazardous physical agents and that, subject to any statutory standards and in consultation with industry and labour, the Authority issue a code of practice for the application in mines and plants of the Threshold Limit Values of the American Conference of Governmental Industrial Hygienists.

This recommendation is made with the clear understanding that TLVs as defined by the ACGIH (see n.4) are guidelines and not statutory standards.

The Commission has further recommended that with respect to both ionizing radiation and asbestos dust the Mines Inspection Branch establish a sequence of two ceiling values based on averaging over a time interval that is a small fraction of a shift (perhaps fifteen minutes). When the first ceiling level is exceeded, corrective action must be initiated immediately, and when the second ceiling level is exceeded, regular workers must be withdrawn from the offending locations until conditions are corrected. Such a regulation does not preclude the protection of regular workers by the wearing of respirators for limited periods in a small number of designated work locations.

The procedure of defining 'ceiling' short-term operational levels deserves to be extended as a means of ensuring that 'worst case' exposure conditions are dealt with as part of the over-all problem of limiting time-weighted average exposures over working shifts. Recommendations have been made for the establishment of codes of practice for engineering monitoring. Common sense suggests that environmental samples be taken when well-informed workers consider a work situation to be unusually hazardous.

With respect to individual encounter, there are very great difficulties in determining both acute and chronic exposures. Acute encounters are for the most part accidental, and instrumentation of an appropriate form to assess the circumstances is unlikely to be present. The Commission has recommended mandatory continuous monitoring at locations where acute exposures recur. With acute events it is essential to document the circumstances in personal health records and to conduct selective medical surveillance, as has been recommended. For chronic exposure the Commission has placed emphasis on the importance of determining cumulative exposures corresponding to profiles of encounter characteristic of distinctive classes of jobs. Such profiles can be obtained for samples of workers by using portable-instrument technology capable of integrating specific exposures over several shifts. The exposure status of classes of workers, codified through samples and updated from time to time, can play an important role in establishing occupational records for epidemiological research and workmen's compensation. The Commission considers it to be the responsibility of each mining company to develop exposure records for its workers under the guidance of codes of practice issued by the Occupational Health and Safety Authority.

The companies also have the responsibility of maintaining environmental records of over-all operations under codes of requirement, issued and audited by the Mines Inspection Branch.

A key issue is the development, custody, and use of personal occupational health records, which should include records of accidental injuries. X-ray records as prescribed by the Mining Act for persons with a Miner's Certificate are maintained by the Chest Examining Stations now operated by the Ministry of Health. The Commission has recommended that responsibility for maintaining audiometric records and records of acute and chronic encounter with toxic substances rest with the mining companies. It has proposed that representative cumulative exposures associated with characteristic profiles of encounter with toxic substances and noise be established for sample populations of workers in distinctive classes of jobs, and that these representative exposures be codified and included in per-

sonal occupational health records as estimates of exposure and risk. The importance of linking personal health and safety records to the system of social insurance numbers and Miner's Certificate numbers (where issued) has been emphasized. It is desirable that as far as feasible there be a complete file of all occupationally related personal health and injury data for a particular person placed under local medical supervision. These records should be designed to serve the immediate well-being of the worker and to provide basic data for studies of the health of groups of workers. To ensure proper confidentiality and use they should be under the responsible medical supervision of a company medical director or a superintending consulting physician. The Commission believes that the mining industry as a whole has not been providing the level of occupational health supervision workers are entitled to and endorses the substance of the recommendations of the Ministry of Health in this regard.[82] In a major Swedish mining company visited by the Commission the medical director is responsible for supervisory surveillance of both the health and safety of the workers. In another area smaller mines are grouping to establish a collective service. The Commission recommends:

That the mining industry establish for its employees, where such is not now provided, occupational health surveillance by a supervising medical director or consultant experienced in occupational medicine.

The realization of such a service will be difficult because few medical graduates of Canadian medical schools are oriented toward the challenges of preventive medicine in occupational health. This fact reflects the emphasis in the health-care system on disease as contrasted with prevention.

Personal occupational health records should be confidential to the person and to the supervising physician and their release as individually identifiable records to other persons within or outside the company should be subject to the informed consent of the worker. In this regard the medical supervisor of the occupational health of workers is faced with basic ethical issues which need to be understood by the worker as well as by management.[83] The Commission further recommends:

That the labour unions individually or in consort appoint to their staff a consulting specialist in occupational medicine.

The intent of this recommendation is to ensure that the unions have the continuing advice of a person who is able actively to participate in the network of professional relations in occupational medicine.

Statistical studies of the health status of groups of workers, for example through the methods of epidemiology as used by the Ministry of Health and the Commission and cited in the report, are necessary to identify existing and emerging health problems. For such purposes it is essential that there be agreed protocols whereby research groups can gain access to and use records for statistical purposes while preserving the confidentiality of individuals and, as appropriate, employers. The Commission strongly believes that the Occupational Health and Safety Authority should be given a carefully defined statutory right of access to all personal occupational health records. Further, it is proposed that protocols for research on such records by government, university, or other agencies be approved by the Authority on the recommendation of a protocol review committee consisting of widely representative lay and professional persons, except in those instances where the protocol has already been subject to review by a human experimentation committee as is customary in university-based research. The purpose of a protocol review committee, at the Authority level would be to approve the ethical aspects of the research but not to judge the scientific merit of the work. Such judgment is properly rendered by the agency funding the study. The Commission suggests that the Occupational Health Protection Authority convene a seminar of interested parties to discuss the conduct of epidemiological studies in occupational health, including needs for computer-based files at company and provincial levels.

In the foregoing review the Commission has emphasized the need for linking occupational health records through common code identification provided by social insurance numbers and Miner's Certificate numbers (see n. 104 in chap. 3). For some kinds of research there is likely to be need for a central depository of records. The Commission suggests that the Workmen's Compensation Board be designated for that purpose. The Board has stated that it does not consider that it bears direct responsibility for epidemiological assessment of emerging problems of health and safety among workers.[84] Indeed, this responsibility should ultimately rest with the Occupational Health and Safety Authority. At the same time the Board's statistical records on compensation are of prime importance to any general review of the status of the health and safety of mine workers, and the Board has assisted the Ministry of Health by setting up such special programmes as the Uranium Nominal Roll. The Commission's intent is that the Board should have the resources to provide statistical support to perform research in occupational health and to act as the official central depository for confidential records where such is needed. To fulfil this role it will be important for the Board, in co-operation with the research com-

munity, to devise file structures and data bases suited to the investigation of sample populations selected in accordance with the topic of research.

The subject of occupational health records is a major one for which there are no simple solutions. The proper roots lie in well-maintained personal occupational health records under effective medical supervision. These root elements should be linked by common codes, and central deposition should be directed primarily to problems of research.

The Commission considers there to have been far too little research on the health and safety of workers in mines in Ontario. The excellent epidemiological studies by the Ministry of Health have been conducted in response to major emergent problems. The Occupational Health Protection Branch has not had the resources to carry out exploratory research designed to assess the likelihood of there being problems. Research on the statistics of accidents, such as that conducted by the Commission, has been non-existent. It is imperative that this situation change. The Commission proposes that the government fund research at an annual level of 1.5 per cent of the direct annual costs of workmen's compensation for accidents and industrial disease in the mining industry. The direct costs of such compensation are currently about 6 per cent of gross wages, which total about $400 million. Thus compensation costs are about $25 million per annum, and 1.5 per cent of this sum is $375,000 dollars.

In addition to a general commitment by government to research on health and safety in mines it is important that the joint health and safety committees have a direct means of initiating studies of common pragmatic concern. The Commission conceives of the joint health and safety committees of one or a number of companies proposing in consultation with competent researchers the conduct of particular studies. The Commission believes that the policy recently adopted in Sweden[85] of levying a fixed percentage of the wages of workers provides an equitable means of establishing a fund for this purpose. The Commissions recommends:

That under the Workmen's Compensation Act provision be made for the levying on all employers in class 5 an amount of 0.03 per cent of wages currently subject to levy under the Act to create a fund for research on occupational health and safety by the joint labour-management health and safety committees.

The foregoing fund would be about $125,000 or about 1/200th of the current direct costs of compensation for accidents and industrial disease in the mining industry. The Commission proposes that both of the foregoing funds totalling together about 2 per cent of the direct annual costs of workmen's compensation, that is, about $500,000 per annum, be adminis-

tered by the Occupational Health and Safety Authority, with the guidance of a peer review Committee on Research.

1 *Health Hazards of the Human Environment*, World Health Organization, Geneva, 1972
2 *Airborne Contaminants Mining, Milling, Smelting and Refining*, 3d ed., Mines Accident Prevention Association of Ontario, 1973; E. Mastromatteo, 'Noxious gases in mining operations,' *Canadian Mining Journal*, October 1967, 75–7
3 Jan H. Reimers and Associates Ltd, *Study of Health and Safety in Ontario Extractive Metallurgical Plants*, 7 November 1975. This report was prepared by consultants in extractive metallurgy as a Commission resource document. The Engineering and Labour Advisors to the Commission subsequently visited metallurgical plants and the related labour unions with the Commissioner and the consultants.
4 A part of the definition of Threshold Limit Values for chemical contaminants as used in the USA is as follows:

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness ... Threshold limit values refer to time-weighted concentrations for a 7- or 8-hour workday and 40-hour workweek ... Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday ... Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast-acting and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling 'C' limit that should not be exceeded ... They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations ... These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline ... They are not intended for use, or for modification for use (i) as a relative index of hazard or toxicity ... In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical. (Preface, 'Chemical contaminants,' *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment With Intended Changes for 1975*, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1975)

The documentary basis for TLVs is published in *Documentation of the Threshold Limit Values for Substances in Workroom Air*, 3d ed., American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1971. For related concepts see chap. 2, n. 74, and *Permissible Levels of Occupational Exposure to Airborne Toxic Substances*, World Health Organization, Technical Report Series No. 415, Geneva, 1969.
5 The following are representative page references in the transcripts to union concern about blasting fumes and practices: 1116, 1689–91, 2182, 2234, 2243–5, 2588, 2594–5, 2760, 3008, 4168–70. In the decade 1965–75, 11 out of 213 fatalities were caused by explosives.
6 J.M. Rogan, *Medicine in the Mining Industries*, London, 1972, chap. 11
7 Non-fatal chemical burns to the skin at 12.9 per annum represent a small part of accidents leading to burns of the skin. Of these the five occurring underground were mainly from

cement used in backfill. In the three-year period 1972–4 an average of seventy non-fatal compensable burn injuries per annum were caused by agents other than chemicals. The agents involved were molten metal (35), other hot materials including steam and hot liquids (24.4), fires (8.3) and electricity (2.3). This total of seventy compensable burn injuries per annum were distributed as follows: reduction plants (52.7), underground (6.7), shops and surface (7.6). As would be expected, the great majority of these burn injuries occur in reduction plants, where process temperatures are highest. With respect to electrical burns it is noted that in the decade 1965–74, two of 213 fatal injuries were by electrocution.

In the period 1972–74 one non-fatal compensable injury was caused by ingestion. A driller attempting to siphon diesel fuel from a barrel into a scooptram used his mouth and swallowed some fuel.

8 Compensable injuries per annum from chemical absorption, at 15.6, are a small fraction of all eye injuries. Compensable injuries to eyes, resulting from a 'foreign body' in the eye, for the three-year period 1972–4 averaged 90.3 injuries per annum distributed as follows: 53 underground, 31.7 in reduction units and 15.6 in shop and surface units. In addition to these injuries there were three per annum from flash burns of radiation from welding arcs. These figures total 108.9. About half of these injuries occur underground. There is strong evidence, particularly for certain companies, that eye protection is not meticulously used. The foregoing figures exclude injuries caused by being struck forcibly on or in the eye by agents that would break or displace eye protection.

9 The following are representative page references in the transcripts to union concern about chemicals other than blasting fumes: 1023–4, 1357, 1424, 1438–9, 1724–32, 1846–62, 1869–80, 1928, 1961–2, 2116–20, 2168–9, 2183, 2204–5, 2335, 2515–31, 2870, 2972, 3001, 3406, 3422, 3561, 3564–75, 3582, 3680, 3692–3704, 3900–5, 4036–8, 4661–2, 4879–80, 4896–9.

10 Mining Act, Sections 214(1), (4), (6)

11 Brief 142, 28, 32

12 See for example Brief 51, 34

13 For example, *Reagents and Chemical Hazards*, Electrowinning Department, Copper Refinery, INCO Ltd, Aug. 1974

14 *Guidelines for Labelling of Toxic Chemicals for Use in Ontario Industries*, Occupational Health Protection Branch, Ministry of Health, Ontario, 1975; *Guidelines for the Safe Handling of Toxic Chemicals for Use in Ontario Industries*, Occupational Health Protection Branch, Ministry of Health, Ontario, 1975

15 See for example Exhibit 55.

16 For example, in the Copper Cliff Nickel Refinery of INCO Ltd and in Falconbridge Nickel Mines Ltd

17 Workmen's Compensation Act (WCA), Section 1(*l*)

18 WCA, Regulation 834, Schedule 3

19 Until the publication of this report this number was not known to the Board. An earlier estimate, cited in chap. 3, was an excess of 26 cases.

20 The epidemiological identification of the excess of lung cancer in the silver and cobalt oxide plant is to be found in R.B. Sutherland, 'Respiratory cancer mortality in a smelting and refining company in Ontario 1928–1952,' Thesis, Diploma in Industrial Hygiene, University of Toronto, 30 April 1958, and in 'Follow-up report on pulmonary cancer mortality 1930–1963 Deloro Smelting and Refining Company Ltd,' Department of Health, Ontario, unpublished. Arsenic was present in the ores and packed by hand in barrels as a by-product in the form arsenic trioxide.

21 The compensation was for a person who had worked sixteen years is asbestos mines in the province of Quebec before working a further twenty-one years in Ontario asbestos mines in the period 1950–70. Some thirty-four cases of cancer among workers in asbestos manufacturing plants have been compensated. Of these, twenty-two cases were lung cancer and twelve were cases of mesothelioma.

22 R.B. Sutherland, 'Report on respiratory cancer: the International Nickel Company of Canada, Ltd, Port Colborne Refinery (among men employed during the period 1930 to 1957 inclusive),' Department of Health, Ontario, 1959, unpublished. The operations considered to be contributing high risks were cupola and sintering furnaces. Employment solely at calcining or anode furnaces was not associated with increased risk of cancer of the lungs or nasal cavities. The Workmen's Compensation Board initiated compensation early in 1961 on the basis of the evidence in Dr Sutherland's report. For all cases of lung, nasal, or sinus cancer in the population continuing at risk, the current practice of the Workmen's Compensation Board is that one year of exposure is necessary to establish a claim (Transcript, 4725–7).

23 E. Mastromatteo, 'Nickel: a review of its occupational health aspects,' *Journal of Occupational Medicine*, 9 March, 1967, 127–36. This review contains data updating ibid. to 1965.

24 R.B. Sutherland, 'Mortality among sinter plant workers: International Nickel Co. of Canada, Ltd, Copper Cliff Smelter,' Department of Health, Ontario, 1969, unpublished. The operation considered to be contributing the high risk was sintering furnaces in which the sinter produced contained less than 1 per cent sulphur. The Workmen's Compensation Board initiated compensation in 1969 in response to Dr Sutherland's report. The current practices of the Board are that one year of exposure is necessary to establish a claim except for exposures arising before 1952, in which case six months of exposure is necessary to establish a claim (Transcript, 4725–7).

The Ministry of Health, with the assistance of the company and the United Steelworkers of America, has developed a nominal roll of some 724 persons for whom there is documented evidence of exposure. The Ministry is conducting biannual medical surveillance based on chest X-rays and sputum cytology for the population at risk living in the Sudbury area, and chest X-rays are arranged for those who have moved away. On sputum cytology see Joan C. McEwan, 'Cytological monitoring of nickel workers,' *Annals of the New York Academy of Sciences*, forthcoming, paper presented at the Conference on Occupational Carcinogenesis, New York, March 1975.

25 *Nickel: Medical and Biological Effects of Environmental Pollutants*, National Academy of Sciences, Washington DC, 1975: for nickel carcinogenesis see chap. 6 and for Ontario experience 152–6.

26 *Collective Bargaining Agreement Between Inco Ltd and United Steelworkers of America*, 19 July 1975. *Letter of Agreement*, 10 July 1975, appended to Article 17

27 Nickel carbonyl $Ni(CO)_4$ is a mobile colourless liquid with a high vapour pressure. It boils at 43°C at atmospheric pressure and begins to decompose at 60°C, producing finely divided nickel and carbon monoxide. There are established industrial uses for nickel carbonyl. It is also generated and released into the atmosphere as a product of combustion of fossil fuels and may be present in cigarette smoke. See *Evaluation of Carcinogenic Risk of Chemicals in Man Some Inorganic and Organometallic Compounds, Volume 2*, International Agency for Research on Cancer, World Health Organization, Lyon, 1973, 129–32. It occurs as a process product in pressured vessels in the refining of nickel in the new Copper Cliff Nickel Refinery of INCO Ltd which began operating in March 1973. In the period April 1959 to 1970, preceding the opening of this nickel refinery, a pilot plant was operated at a carbonyl research station at Port Colborne where thirty-five persons were employed. The current TLV for nickel carbonyl, cited in Table 54, is 0.001 parts per million, with a notice of intended change to 0.050 parts per million. The nature and treatment of acute effects of nickel carbonyl are reviewed in Mastromatteo, 'Nickel,' 128. The company maintains a special clinic at the refinery and has well-defined standard procedures of response for any worker who may have suffered an acute inhalation.

28 F.W. Sunderman jr, 'The current status of nickel carcinogenesis,' *Annals of Clinical Laboratory Science*, 3 1975, 156–80; nickel carbonyl is treated in Table 8 and on 165–6.

29 *Evaluation of Carcinogenic Risk*, 134–5

30 A concise review of experience in Wales is given in *Nickel: Medical and Biological Effects*, 144–52
31 R. Doll, L.G. Morgan, and F.E. Speizer, 'Cancers of the lung and nasal sinuses in nickel workers,' *British Journal of Cancer*, 24, 1970, 624
32 *Evaluation of Carcinogenic Risk*, 144
33 US Department of National Health and Welfare, NIOSH, *Criteria for a Recommended Standard ... Occupational Exposure to Asbestos*, Publication HSM 72-10267, 1972. This document provides an extensive review of the literature on asbestos to 1971 and documents the elements for a standard based on a time-weighted average exposure of 2.0 fibres per cubic centimetre greater than 5 microns in length averaged over an eight-hour day and with a maximum allowable concentration over a fifteen-minute averaging period of 10 fibres/cc. The 2.0 fibre standard was adopted by the Ministry of Health in 1975 and is now used as a guideline by the Ministry of Natural Resources for Ontario asbestos mines. The Occupational Safety and Health Administration, which sets standards in the USA for industry other than mining, has now proposed a revised standard of 0.5 fibres/cc: see 'Occupational exposure to asbestos – Notice of proposed rulemaking,' *Federal Register*, Department of Labour, 40, no. 197, 9 Oct. 1975. In the United States federal regulations for mines are set by the Mining Enforcement and Safety Administration, which has published a standard of 5 fibres/cc greater than 5 microns in length and a maximum allowable concentration of 10 fibres/cc. *Federal Register*, 39, no. 127, 1 July 1974; I.J. Selikoff, E.C. Hammond, and J. Churg, 'Asbestos exposure, smoking and neoplasia,' *Journal of the American Medical Association*, 204 1968, 196; J.C. McDonald et al., 'Mortality in the chrysotile asbestos mines and mills of Quebec,' *Archives of Environmental Health*, 22, 1971, 677; Health and Welfare Canada, Environmental Health Directorate, *Report of the Asbestos Working Group*, Feb. 1976. This document provides a review of the asbestos mining industry in Canada, giving the locations of mines, milling capacities, types of fibre, major product uses, and product manufacturers. It documents the number of known cases of asbestosis and of mesothelioma by province and makes recommendations to the provincial and federal governments, including a recommendation for a dust standard of 2 fibres per cubic centimetre and another that non-smoking be a condition of employment in exposure to asbestos. The problems of health in the asbestos industry of Quebec are currently being studied by a committee which has issued a preliminary report, the results of which should be highly relevant to Ontario asbestos mines: René Beaudry et al., *Rapport Préliminaire Comité d'étude sur la salubrité dans l'industrie de l'amiante*, Quebec, April 1976.
34 Health and Welfare Canada, *Report of the Asbestos Working Group*, 8
35 Selikoff et al., 'Asbestos exposure'
36 The person had worked intermittently in gold mines and silica mines from 1928 to 1956 in Quebec and Ontario. He worked at an Ontario asbestos mine from 1956 to 1975 and was compensated for mild asbestosis in the year of his retirement. In Ontario industry as a whole in the five years 1970–4, 82 cases of asbestosis were compensated, and among these were eight cases of mesothelioma (see Health and Welfare Canada, *Report of the Asbestos Working Group*, 24, 26).
37 *Introduction to Lung Diseases*, American Lung Association, USA, 1973, 14, 69
38 While measurements with the konimeter using acid and heat treatment of the slides are suitable for isolating free silica, they are not well suited for determining the levels of airborne toxic substances not related to silicosis. Total dust measurements by mass are now common in reduction plants and an ad hoc standard of 7.5 milligrams per cubic metre has been stated to have been set for one smelter complex by the Mines Engineering Branch on the recommendation of the Ministry of Health. See Brief 139, 12d, 13d; Brief 52, 27–9 and Appendix 14.
39 *Morbidity and Mortality in Selective Occupations at The International Nickel Co. of Canada Ltd., Copper Cliff, Ontario 1950–67*, Health Studies Service, Environmental

Health Services Branch, Ontario Department of Health, 113. This undated study is based on a sample population of 831 persons divided for comparison purposes into persons working in a smelter-converter area, in a mill and separation area, in parts of a copper refining operation, including the tank house area, mechanical department, and yard and transport areas, and in an underground mine. The morbidity study was based on a work history, including records of absences and diagnoses of the attending physician.

40 *Chronic Obstructive Lung Disease Among Persons Employed for Ten Years and More in the Converter Plant of the International Nickel Company of Canada, Ltd*, Copper Cliff, Ontario, Aug./Sept. 1973, Ministry of Health, March 1976. This study examines evidence of chronic bronchitis and pulmonary function changes among a population of 310 converter workers and a comparison population of 64 refinery workers. Each person at the time of the survey had ten years or more experience in the designated areas. The study is based on personal contact with the workers to obtain a medical history through a standard questionnaire related to chronic bronchitis, determine smoking habits, and conduct lung function tests.

Lung function tests involve mechanical measurements of a person's capacity to inhale and exhale. Two of these are FVC (Forced Vital Capacity): the total volume of air, expressed in litres, which is expelled from the lungs on maximum effort following a deep inspiration; and FEV_1 (Forced Expiratory Volume, One Second): the volume of air expelled from the lungs within one second.

41 L.C. Neri et al., 'Chronic obstructive pulmonary disease in two cities of contrasting air quality,' *CMA Journal*, 113, Dec. 1975, 1043–6; the cities compared were Sudbury and Ottawa.

42 Victor E. Archer, Thomas J. Smith, and J. Dean Gillam, 'Chronic sulfur dioxide exposure in a smelter: I indices of chest disease,' paper submitted to the *Journal of Occupational Medicine*; Thomas J. Smith, William L. Wagner, and David E. Moore, 'Chronic SO_2 exposure in a smelter: II exposure to SO_2 and dust 1940–74,' paper submitted to the *Journal of Occupational Medicine*; Thomas J. Smith et al., 'Pulmonary impairment from chronic exposure to SO_2,' paper submitted to the *New England Journal of Medicine*.

43 See Lowe et al. in J.C. Gilson, 'Occupational bronchitis?' *Proceedings of the Royal Society of Medicine*, 63, 1970, 863.

44 *Documentation of the Threshold Limit Values for Substances in Workroom Air*, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1971, 238–9; this document refers to a TLV of 5 ppm. US Department of National Health and Welfare, NIOSH, *Criteria for a Recommended Standard ... Occupational Exposure to Sulphur Dioxide*, 1974; this report documents a recommendation for a TLV of 2 ppm.

45 Gilson, 'Occupational bronchitis?'

46 *Survey of Certain Conditions of the Respiratory Organs Among Persons Employed Underground And In Surface Crushers and Mills of Two Operating Mines at Elliot Lake, Ontario, February 17–March 30, 1974*, Ministry of Health, Ontario, 28 April 1975, 25–9

47 See ibid., Tables 11, 12. Close quantitative comparisons of prevalence of chronic bronchitis between different sample populations, such as the converter and refinery workers, the uranium mine workers, and the Ottawa male population, are not justified unless the samples are matched for age distribution, smoking habits, and durations of exposure where applicable. For the sources cited such matching has not been made.

48 Gilson, 'Occupational bronchitis?' Table 6; G.K. Sluis-Cremer, L.G. Walters, and H.S. Sichel, 'Chronic bronchitis in miners and non-miners: an epidemiological survey of a community in the gold area of Transvaal, *British Journal of Industrial Medicine*, 24, 1967, 1; F.J. Wiles et al., 'Chronic bronchitis in miners,' *National Research Institute for Occupational Diseases of the South African Medical Research Council*, 1972, 28–38; W.K.C. Morgan and N.L. Lapp, 'State of the art, respiratory disease in coal miners,' *American Review of Respiratory Disease*, 113, 1976, 531–59 (industrial bronchitis is reviewed on 554–5); Commission of the European Communities, *Research on Chronic*

Respiratory Diseases, Industrial Health and Medicine Series No. 18, Luxembourg, 1976, chap. 3, 'Epidemiological investigation,' 76–113; J.C. McDonald et al., 'Respiratory symptoms in chrysotile asbestos mines and mill workers of Quebec,' *Archives of Environmental Health*, 24, 1972, 358.

49 Personal communication from the director, Medical Bureau for Occupational Diseases, Department of Mines, Republic of South Africa, to the Commission's medical consultant, Oct. 1975. See also Republic of South Africa, *Occupational Diseases in Mines and Works Act*, 1973, Sections 1(XIV)(d)(e) and 44(1)(b)(c) and 2(c)(d).

50 *Survey of Certain Conditions*, 28

51 E. Mastromatteo, *Toxic Effects of Diesel Engines and their Threshold Limit Values*, Seminar on Underground Diesel Operations, Sudbury, April 1971 (this paper discusses the use of TLVs for the multiple components of diesel exhausts); H.E. Stokinger, *Toxicology of Diesel Emissions*, US Bureau of Mines Information Circular, IC 8666, 1975, 147–58; J.A. Kibelstis, *Medical Effects of Diesels Underground*, US Bureau of Mines, Information Circular 8666, 1975 159–67 (this paper reviews the short-term influences of diesel fumes on workers); for technical characteristics related to mining as based on substantial co-operative Canadian research see Brief 127, 10–14.

52 Richard J. Waxweiler, Joseph K. Wagoner, Victor E. Archer, 'Mortality of potash workers,' *Journal of Occupational Medicine*, 15, June 1973, 489. One of the eight mines studied began using diesel engines underground in 1949, another in 1957.

53 Dr Victor E. Archer informed the Commission that the National Institute of Occupational Safety and Health in the United States is mounting such a study with the Mine Enforcement and Safety Administration.

54 *Underground Diesel Engine Code 1973*, Ministry of Natural Resources, Ontario. Section 3 of this code, which is currently being revised, states:

The volume of ventilating air shall be sufficient to ensure that at no place in a mine using diesel engines, will there be a concentration of noxious gases exceeding the safe limits required by the following and no engine shall operate if: (*a*) The carbon monoxide content of the undiluted exhaust after the scrubber exceeds 1500 parts per million or 0.15 per cent. (*b*) The carbon monoxide content of the atmosphere adjacent to the engine exceeds 50 parts per million or 0.005 per cent. (*c*) The carbon monoxide content in the air of the general atmosphere in the haulageway exceeds 20 parts per million or 0.002 per cent. (*d*) The nitrogen dioxide content of the atmosphere adjacent to the engine exceeds 5 parts per million or 0.0005 per cent. (*e*) The aldehyde content of the atmosphere adjacent to the engine exceeds 2 parts per million or 0.0002 per cent (measured as formaldehyde). (*f*) The carbon dioxide content of the atmosphere adjacent to the engine exceeds 5000 parts per million or 0.50 per cent.

This code sets down no limit for particulates in the exhaust or for oxides of sulphur, but the current revision of the code is expected to do so. With respect to ventilation the Code states: 'in general, for design purpose, 75 cfm of ventilating air supply per rated brake horsepower of the engine is required in all areas of operation.'

55 See Brief 127.

56 See Stokinger, *Toxicology of Diesel Emissions*. The toxic substances for which limits are currently set in the diesel code are listed in n. 54, and their immediate effects are discussed by Kibelstis, *Medical Effects of Diesels Underground*.

57 Stokinger, *Toxicology of Diesel Emissions*, 156

58 William Burns, *Noise and Man*, 2d ed., London, 1973; W. Burns and D.W. Robinson, *Hearing and Noise in Industry*, London: HMSO, 1970

59 There are many other effects of intense noise on man the occupational significance of which have not clearly been established. The Worken's Compensation Board has received no claims for injury from noise other than for hearing loss. See for example, Burns, *Noise*

and Man, chap. 8; K.D. Kryter, *The Effects of Noise on Man*, New York, 1970, 491–516; Thomas Cummings, 'Effects of noise on hearing: two group studies,' MS Thesis, Department of Preventive Medicine and Biostatistics, University of Toronto, 1976. The Commission has not been concerned with infective diseases or with drugs that induce deafness, nor with traumatic deafness induced by explosion or by physical objects entering the ears or striking the head.

60 P.W. Alberti, P.P. Morgan, and J.C. LeBlanc, 'Occupational hearing loss – an otologist's view of a long-term study,' *The Laryngoscope*, 84, Oct. 1974, 1822–34; this paper reports characteristics of 719 consecutive patients referred by the Workmen's Compensation Board of Ontario for adjudication of hearing loss of presumed occupational cause. Of this group 49.5 per cent were miners. See also Cummings, 'Effects of noise on hearing,' 6, 7.

61 Lump-sum payments may be made in lieu of a pension for the smaller levels of compensation.

62 *Permanent Disability Rating Schedule*, Workmen's Compensation Board, 15 Feb. 1972

63 Because a person's hearing may deteriorate with time, he may submit to the Board a sequence of claims with the object of having a previous award adjusted. Thus in due course medical aid cases may receive permanent disability awards of increasing percentages. The terminology 'first allowed' and 'latest settlement' pertain to this matter.

64 Transcript, 1110

65 Transcript, 2745

66 See Burns, *Noise and Man*, chap. 11.

67 For a concise review of the problems of occupational noise and the means to deal with it see: *Occupational Noise*, Project Team Report, Ontario Ministry of Health 4 Dec. 1974. Procedures for conducting audiometric tests on the ears of workers are given in *Occupational Audiometric Testing Programmes. Recommended Standard and Guidelines*, Ontario Ministry of Health, 1974; this document contains a sample of typical audiometric records. For a more elaborate exposition of the basis for a noise standard see US Department of Health, Education and Welfare, *Occupational Exposure to Noise, Criteria for a Recommended Standard*, NIOSH Report HSM 73-11001, Washington, 1972.

Continuous noise consists of a jumble of sound waves of many different frequencies spanning the audible range. The frequencies of special concern are those in the range of human speech, from about five hundred cycles per second to about three thousand. A noise at a particular location has a definite distribution of frequencies and intensities of atmospheric pressure variations. A weighted mean of these intensities at all frequencies relative to a chosen reference level of pressure can be measured by a sound level meter whose reading corresponds to the formula

$$\mathrm{dB(A)} = 20 \log_{10} \frac{P}{P_0},$$

where dB(A) means decibels using the A weighting scale, P is the root mean square pressure level of the source of noise as measured with the A weighting scale, and P_0 is the root mean square reference level, which is 20 micronewtons per square metre. This level is about the threshold of audible sound at the frequency of greatest sensitivity in young persons with clinically normal ears. The ear is not equally sensitive at all frequencies, and the A weighting scale is chosen to approximate to the relative sensitivity of the normal human ear at different frequencies. The loudness of sounds as perceived by the ear varies approximately as the logarithm of the sound pressure level. Because of the logarithmic function used, the number of decibels increases by the number 6 (almost) when the sound pressure P doubles, and decreases by 6 when it halves. Thus a noise with a dB(A) rating of 96 dB(A) has twice the pressure level of a noise of 90 dB(A) and a noise of 102 dB(A) has a pressure level four times that of a noise of 90 dB(A). The decibel levels of independent noise sources do not add directly. To obtain the resultant dB(A) level it is necessary to

determine the separate mean square sound pressure levels, add these, and then determine the decibels.

68 *Noise Survey Procedure*, Mines Accident Prevention Association of Ontario, 1973

69 For example, *Noise Survey Report of the Campbell Red Lake Mine, Balmertown, Ontario, Subject: Screening Survey of Surface and Underground Operations*, Mines Accident Prevention Association of Ontario, May 1974

70 Mining Act, Section 173(2)4, (3), (9)

71 *Noise Control and Hearing Protection Code*, Division of Mines, Mines Engineering Branch, Ontario Ministry of Natural Resources (1 July 1974). The allowed noise levels are the same as those in the Industrial Safety Act, Section 111, under Ontario Reg. 259/72, s. 111. A formula is provided for determining the effective exposure of a person who experiences different levels of noise during a shift.

72 US Environmental Protection Agency, *Public Health and Welfare Criteria for Noise*, Publication No. 55019-73-002, 27 July 1973, 1–4

73 United States Department of the Interior, *Hearing Conservation for the Mineral Industry*, Bureau of Mines Information Circular IC 8564 (1972); Also see US Department of Health, Education and Welfare, *Occupational Exposure to Noise*, NIOSH, Table 7. A skimobile operating at full speed may produce a noise level of 105–115 dB(A) at the driver's head (see Cummings, 'Effects of noise on hearing,' Table 10). Isolated impact noise from rifles and shotguns and high level sound from loudspeakers are sources of hazard for some persons. Typcial lower noise levels are as follows: business office 55, conversational speech 65, street corner traffic 75.

74 M Savich and J. Wylie, *Noise Attenuation in Rock Drills*, Canadian Mining Research Centre, Energy, Mines and Resources Canada, April 1975; this document provides a review of the state of the art. Exhaust mufflers on conventional hand-operated compressed-air drills have succeeded in lowering resultant noise levels by about 6 dB(A), but the percussive noise of steel on rock remains. (See Table 63.) For the viewpoint of an organization of manufacturers see Brief 116 and the related transcript.

75 A new organization called the Mining Industry Research Organization of Canada has been established by a group of six large Canadian mining companies (News release, 7 April 1976). MIROC has indicated that improvement in underground lighting is a priority. The Commission strongly endorses this choice.

76 Transcript, 1121

77 Well-designed ear plugs properly fitted and kept adjusted can produce attenuation of noise of over 20 dB(A) at frequencies above five hundred cycles per second. Well-fitted ear muffs worn without glasses can produce attenuation of over 30 dB(A) and combined plugs and muffs about 40 dB(A). (See US Department of the Interior, *Hearing Conservation for the Mineral Industry*, Figure 8 et. seq.) The MAPAO makes the following recommendations concerning the use of ear plugs and muffs: 'Properly fitted insert type of hearing protectors should provide adequate protection to all empoyees working in locations where noise levels are below 105 dB(A). For noise levels in the 105–118 dB(A) range, ear muffs are recommended. Over 118 dB(A) plugs and muffs are recommended.' (*Noise Survey Report of the Campbell Red Lake Mine*)

78 Transcript, 1113

79 *Occupational Audiometric Testing Programmes*, Ontario Ministry of Health

80 When a person with normal hearing is presented with a pure tone of a given frequency there is a certain minimum sound level at which it will just be audible. As that person's hearing deteriorates it takes a more intense sound at this frequency to evoke hearing. The change can be measured in decibel units, and the amount is called the increase in threshold at the test frequency.

81 For persons over sixty years of age 0.5 decibels per year in excess of sixty years is subtracted from the observed increase in threshold at each frequency as an allowance for the natural deterioration of human hearing with age. This effect is called presbycusis.

Decibel measurements are in the scale of the International Organization for Standardization.

82 Brief 142, 8–10

83 Robert Murray, 'Ethics in occupational health practice,' chap. 21 in R.S.F. Schilling, ed., *Occupational Health Practice*, London, 1973; 'The occupational physician,' editorial, *Journal of the Society for Occupational Medicine* 25, 1975, 37; Irving R. Tabershaw, 'Whose "agent" is the occupational physician?' *Archives of Environmental Health* 39, Aug. 1975, 412–16; Robert R.J. Hilker, 'In-plant medical services,' *Archives of Environmental Health* 30, Aug. 1975, 409–11.

84 Transcript 4712, 4785–6

85 *Arbetarskydds Fondens Verksamhet, 1974*, Stockholm. The amount first levied on wages was 0.03 per cent in 1971, raised to 0.075 per cent in 1973.

6

Policy for occupational health and safety in the mining industry

In responding to its broad terms of reference the Commission has been guided by the evidence and opinions presented to it in the public hearings. Industry and labour have expressed deep concern not only about the facts of industrial disease and injuries from accidents but also about the effectiveness of the institutional arrangements between government, industry, and the workers for dealing with the hazards at work and about governmental policy for occupational health and safety that such arrangements reflect. The Commission has conducted studies and investigations of the problems of silicosis and dust, of lung cancer and ionizing radiation, of accidents and injuries, and of other hazards to health and safety, including hearing loss and noise. These studies and investigations have revealed what the Commission deems to be defects in the institutional arrangements and procedures for dealing with the hazards to health and safety in the mining industry. While the recommendations in the report have intentionally been derived out of the concrete circumstances revealed by the case studies and investigations, an overriding concern throughout has been to establish a more coherent basis for government, industry, and the workforce to deal with the problems of industrial disease and accidents according to their skills and in accordance with well-defined duties and responsibilities. The problems that underlie the issues of health and safety in the mines are first and foremost those of policy and of the performance of the responsibility-system that such policy gives rise to at both the company and the provincial level.

There has been a serious lack of openness on matters of the health and safety of workers in mines. The majority of the information presented in this report has been inaccessible to workers and the public. Workers have a right in natural justice to know about the risks and consequences of the

risks that they undertake at work. Recommendations of the Commission have been designed to ensure that workers and the public, together with industry and the government, share a common framework of understanding of the risks of work and of their consequences in injury and disease. Without such a framework there can be no proper social and political judgment of what constitutes acceptable risks. The Commission believes the lack of such a framework is one manifestation of the absence of an adequate provincial policy on occupational health and safety. The Commission has emphasized that not only the special risks of work but also the voluntary risks of life-style[1] require the open critical attention of society. These classes of risks are not readily separable, and there is as a consequence much misunderstanding of the problems of workmen's compensation, particularly for uranium miners.

Within the internal responsibility-system at the company level, which is the key to the quality of the over-all control of occupational hazards, there has been in many companies an inadequate opportunity for workers to contribute their insight to the assessment of work conditions and to the basis on which management makes decisions on issues of health and safety. The adamantly confrontational character of Canadian labour-management relations has deterred the creation of sensible arrangements for worker participation. Questions of health and safety are not suitable issues for collective bargaining. The Commission has carefully defined a framework for the operation of joint labour-management health and safety committees as bodies contributive to the formulation and review of sound managerial policies and practices. In addition the Commission has recommended the introduction of a system of worker-auditors to provide to management and to the mines inspectorate a new dimension in the auditing of work conditions based on the insight of experienced workers. It is based on, but not identical to, long-established practices in the United Kingdom and Sweden. Within a context whereby workers, other than in the personal act of work, can fulfil a proper responsibility to contribute to the resolution of problems of health and safety, the Commission earnestly hopes that a new measure of labour-management co-operation can emerge. The Commission believes that a part of the wide variation in accident frequencies among different companies is related to the quality of human relations that exist within them, relations in which both management and the collective bargaining unit (where such exists) play crucial roles. A well-founded internal responsibility-system in which labour and management co-operate to control occupational hazards ought to exhibit a high measure of self-regulation for which mines inspection and openly reported environmental and epidemiological reviews can provide the necessary external evaluation.

There has also been, in the Commission's view, an absence of clearly defined roles as a basis for initiative and accountability in institutional arrangements at the provincial level. This characteristic has led, under the stress of burgeoning problems of health and safety at Elliot Lake and elsewhere, to the erosion of trust between unions, industry, and government agencies at the provincial level and therefore at the company level. The seat of this problem of roles and initiatives lies in divided jurisdictions. The law has not facilitated the co-ordination of roles and the implementation of programmes to serve the well-being of workers in the mining industry; it has not kept pace with the rapidly changing social perception of the importance of occupational health and safety.

The split jurisdiction between the Atomic Energy Control Board of Canada and the Ministry of Natural Resources of Ontario, and the related indefiniteness of initiatives at the provincial level, have been explored and recommendations made in the light of the Commission's research on the Uranium Nominal Roll. The health and safety problems of the uranium miners (and not just those at Elliot Lake) provide strong evidence that the historic problem of divided jurisdiction and responsibility between the Ministry of Natural Resources (formerly the Department of Mines) and the Ministry of Health must be resolved. To place this problem in final perspective, it will be useful to review briefly the locus of legal responsibilities for the health and safety of all workers.

Within the province responsibility for the health and safety of workers is divided between the Mining Act, the Industrial Safety Act,[2] the Construction Safety Act,[3] and certain other pieces of legislation. In each of the foregoing major Acts responsibility for compliance is placed upon the employer, whose operations are subject to inspection by government inspectors. The administration of the Mining Act (Part IX) by the Ministry of Natural Resources and the Mines Engineering Branch has been dealt with in detail in the report. The Ministry of Labour administers the Industrial Safety Act and the Construction Safety Act. There are distinctive jurisdictional boundaries between the work of the inspectors under these three acts.[4] The qualifications of the inspectorates are centred in engineering and technology. Supportive services in industrial hygiene and occupational health have been provided to these inspectorates by the Occupational Health Protection Branch of the Ministry of Health either on an ad hoc basis following requests or through interministerial agreements or accords.[5] Outside the general provisions on nuisance in the Public Health Act,[6] which in practice are superseded by the more specific clauses of the Mining and other Acts, the Occupational Health Protection Branch does not have a defined access under the Mining Act to workplaces in mines and therefore

has no basis for taking independent initiative on problems of health and safety arising there. It has not been part of the role of this branch to conduct research on problems of the safety of workers.[7] The Mines Engineering Branch has done excellent work in developing technical standards for safety, for example in mine hoisting, and provisions in Ontario for mine rescue have been exemplary. The Mines Accident Prevention Association of Ontario conducts programmes of education for the industry in accident prevention and some aspects of industrial hygiene. But accidents appear to be regarded largely as issues of unsafe acts and unsafe conditions to be dealt with solely by safety regulations, inspections, and such standards of training and job assignment as are the choice of the industry. Research on the relation of accidental injuries to the nature and timing of work assignments, to training, to the design and operation of machines, to protective equipment, and to environmental factors such as noise and illumination has been neglected.

Such studies into the safety aspects of the human ecology of men and machines are equivalent to the toxicological and epidemiological studies that form the basis for understanding the environmental impact of toxic substances on the health of workers. Is it not, for example, important to know whether or not a miner with a hearing defect is at greater risk of accidental injury than others, so that, if he is, a work adjustment policy can be developed to limit the risks to himself and to his co-workers? There are questions of stress in work which are coupled both to safety and to health. The separation of health from safety for workers is another false dichotomy sustained by policy and the institutional arrangements this policy reflects.

The Commission believes that existing policy on occupational health has unduly limited the initiative of the Occupational Health Protection Branch and that the lack of a complementary investigative capability related to safety has not properly served the well-being of workers in mines. A major group of recommendations of the Commission has therefore been designed to delineate the responsibilities of a new administrative entity called the Occupational Health and Safety Authority. Within this Authority, which will shortly be described, there would be an Occupational Health and Safety Branch having capabilities extended from those of the existing Occupational Health Branch.

In the Commission's view the existing Occupational Health Protection Branch in the Ministry of Health has conducted critically important studies with inadequate resources and has been forced to work in a crisis-to-crisis atmosphere which is not conducive to the development of public understanding of the complexities of occupational health and safety. The Com-

mission believes that the priority given this branch reflects the absence of a legal mandate and as well the massive preoccupation of the provincial health-care system with disease and diagnosis, as contrasted with preventive services. A further manifestation of the latter situation is the absence of a significant emphasis on occupational medicine, industrial hygiene, and ergonomics in medical and engineering education. Few mining companies provide their workers with the services of a resident or consulting physician experienced in occupational medicine, and in the industry there are few active specialists in industrial hygiene.

The Commission has made recommendations to deal with many of these questions but emphasizes that two elements are essential to the institutional arrangements of government for the safety and health of workers in mines. The first has been mentioned, namely, a new administrative structure designated the Occupational Health and Safety Authority; the second requirement is more flexible legislation served by a strengthened inspectorate.

The Commission has reviewed many facets of Part IX of the Mining Act, which, with certain sections of Part XI, establishes the legal framework for the health and safety of workers in mines, the most recent revision of which was proclaimed on 1 January 1971. Part IX of the Mining Act is unusual in that all technical details are incorporated in the legislation, and there is no provision for the making of extensive regulations by the Lieutenant Governor In Council. It has been suggested that the incorporation of all technical detail into the Mining Act provides a degree of stability of legislative rules that allows the mining industry to plan its operations with the knowledge that the rules will not be changed suddenly. An alternative view is that to protect the well-being of workers in an industry subject to rapid technological change this procedure is unnecessarily rigid. The Commission endorses the latter view.

To reach beyond the rigidity of Part IX of the Mining Act the chief engineer of the Mines Engineering Branch has issued, under the general powers conveyed by s. 610(d), various codes establishing guidelines for the measurement of dust, for the operations and emissions of diesel engines, and for the exposure of workers to ionizing radiation and to noise. The Commission has examined the conditions surrounding the issuance of these codes. There have been no codes establishing guidelines for exposure to dust or to toxic chemicals. Since there is no provision in Part IX to incorporate these codes as part of the legislation, the codes are merely interpretive guidelines of the chief engineer and do not have the force of law. The Commission does not believe that this method of issuing codes

provides a satisfactory means for achieving the flexibility and clarity that it considers to be desirable for legislation governing the health and safety of workers in mines.

To provide a legal and administrative structure within which to implement the policy on health and safety for workers in mines reflected in its detailed recommendations, the Commission recommends:

That a Health and Safety in Mines and Plants Act, separate from the Mining Act, be prepared to replace part IX and the relevant sections of part XI of the Mining Act and be administered within an Occupational Health and Safety Authority established in the Ministry of Labour;

That the Health and Safety in Mines and Plants Act consist of a core of general provisions supplemented by regulations the issuance of which is authorized by the Act;

That the general provisions of the Health and Safety in Mines and Plants Act identify the duties and responsibilities of the Mines Engineering and Inspection Branch and the Occupational Health and Safety Branch;

That an Occupational Health and Safety Authority, encompassing the Mines Engineering and Inspection Branch, the corresponding branches under the Industrial Safety Act and the Construction Safety Act, and the Occupational Health and Safety Branch, be established in the Ministry of Labour under an assistant deputy minister.

The structure of the proposed Health and Safety in Mines and Plants Act will be considered first. Many of the general provisions and regulations of a new Act clearly could be adapted from Part IX of the existing Mining Act, which is well-elaborated in many respects. These would include the duties of employers, the safety of equipment, the control of hazards, and so on. But there is need for important additions. The general provisions in the core Act should include, in addition to authority for regulations and the definition of the duties and responsibilities of the Mines Engineering and Inspection Branch and Occupational Health and Safety Branch, the following subjects:

- recognition of codes and schemes of practice as administrative instruments;
- definition of joint worker-management health and safety committees;
- definition of worker-auditors;

- definition of qualifications for supervisors and workers;
- duties of employees;
- definition of medical surveillance and services and the keeping of occupational health and safety records;
- procedures for enforcement of the Act and its regulations through improvement notices and prohibition notices[8];
- the basis for defining general terms such as 'approved,' 'satisfactory,' 'adequate';
- a schedule of subject matter for health and safety regulations to include the setting of engineering and exposure standards and guidelines, and the conduct of research (see *Health and Safety at Work etc. Act* [n.8], Schedule 3).

The central function of the Health and Safety in Mines and Plants Act is to establish a legal basis for a policy for occupational health and safety which has four basic indispensable elements. The first is the setting of a framework of definitions and regulations within which the internal responsibility-system at the company level is required to function in order to limit to acceptable levels the risks to workers in mines and plants. The second is to audit the state of compliance with this framework through inspection. The third is to monitor the introduction of technological change into the industry to the extent such change impinges on the health and safety of workers. The fourth is to evaluate, through epidemiological review, related statistical studies and other research on the machines, materials, and risks of work, the extent and nature of the problems of injury and disease which are the human basis for the legislation. The recommendations throughout the report document the many points where initiative in epidemiological and related research is needed.

The foregoing elements lend themselves readily to the identification of the duties and responsibilities of the Mines Engineering and Inspection Branch and of the Occupational Health and Safety Branch within the proposed Health and Safety in Mines and Plants Act and the associated Authority. The duties of each have two facets, namely, standard setting and auditing, monitoring, and evaluating. The Mines Engineering and Inspection Branch should have the primary responsibility for auditing, monitoring, and evaluating the operations of mines and plants. This it would do by inspecting operations to determine the state of compliance with the existing framework of regulations and by monitoring the introduction of technological change so that regulations can be altered as required to adapt to such changes. In a complementary manner the Occupational Health and Safety Branch takes initiative to review and assess the risks

being encountered by the persons engaged in the operations of mines and plants and in so doing develops a basis of evaluation for the framework of standards which complements that of the Mines Engineering and Inspection Branch. Further, its work is highly relevant to the responsibilities of the Workmen's Compensation Board for establishing and reviewing the basis for compensation of industrial disease and accidents. The Commission believes that its studies demonstrate that to combine the duties and responsibilities described in an Occupational Health and Safety Authority is natural and desirable. To enable this combining of roles in the interests of the health and safety of workers in mines the Commission recommends that the jurisdiction over the proposed new Health and Safety in Mines and Plants Act be moved from the Ministry of Natural Resources to the Ministry of Labour. The duties of the Mines Engineering and Inspection Branch and of the Occupational Health and Safety Branch require that their central staffs be located together, where they can interact personally and exercise their distinctive initiatives in concert.

The proposed Occupational Health and Safety Branch can be established by transfer and extension of the resources and capabilities of the Occupational Health Protection Branch in the Ministry of Health. In proposing the transfer to the Ministry of Labour of an existing health-centred unit and of a mining-centred unit, the Commission is conscious of an important problem of professional identity for the persons involved. Our society is becoming more sensitive to the problems of occupational health and safety, but it has yet to give the public recognition merited by those who devote their professional lives to this field. Government policy and medical and engineering education attest to this fact. Thus engineers associated with mine inspection, whether it be in the United Kingdom or in Ontario, appear to derive professional identity largely from the ethos of the industry, as distinct from their work in controlling the risks to life and limb of workers. The same may be true for medical professionals. The Commission deeply believes that occupational health and safety as an endeavour must be given high public recognition.

Throughout its studies the Commission has emphasized the distinctiveness of the problems of health and safety in mines and reduction plants and believes that a high calibre of engineering and related expertise is necessary in the Mines Engineering and Inspection Branch. The Commission believes that a greater measure of openness and accountability with respect to the risks of work will contribute to the needed public recognition of the worth of careers in the field.

The Occupational Health and Safety Authority that has been proposed would, under an assistant deputy minister as its executive head, be the administrative expression of the conjoint legal requirements expressed in the Health and Safety in Mines and Plants Act, the Industrial Safety Act, and the Construction Safety Act. Its operational elements would be the Mines Engineering and Inspection Branch, the related branches under the other acts, the Occupational Health and Safety Branch, and such additional executive staff as would be necessary for general administration, for the development and formulation of regulations, and for the commissioning of research. The directors of the branches should be members of an executive committee. Since the Workmen's Compensation Board is now under the Ministry of Labour the many important relations with that Board would be facilitated. The Commission observes that the scale of operations of the Occupational Health and Safety Authority, measured in terms of personnel, would be in the order of four hundred persons, that is, it would have critical mass yet not be unwieldy. The Commission believes that the administration of the branches of the Authority should be based on line authority from each director to the field. While the combining of the branches under the Occupational Health and Safety Authority should permit some concertation of work, it should not be an instrument for ill-considered homogenization. If the distinctiveness of the problems of health and safety in the different fields of work are respected, the replacement of the several Acts by a single health and safety at work Act would be a logical step in the evolution of legislative policy.[9]

To provide the Minister of Labour with advice on matters of occupational health and safety the Commission proposes that the Labour Safety Council, which has a Subcommittee on Mines, be replaced by a Council on Occupational Health and Safety, which would reflect the unitary responsibilities of the Occupational Health and Safety Authority and be composed of representatives from industry, labour, education, and the lay public and government. The Council should assist the assistant deputy minister, the executive head of the Authority, to constitute task groups suited to providing advice on new regulations and standards and to advising on the important role of the Authority in education for health and safety (see chap. 4, n.22).

It has been suggested that the MAPAO be transformed in structure by the addition of representatives of labour. Such a proposal reflects in the Commission's view a misconstruction of the potentialities of such an organization. The MAPAO, as one of the accident prevention associations

under the Workmen's Compensation Act, reflects the interests and capacities of the mining industry to engage in self-education in matters related to health and safety. This is a clear, limited, and, in the Commission's view, useful role within the whole responsibility-system. The labour unions in the mining industry have an opportunity for a comparable role in self-education. The Minister's Council related to the Occupational Health and Safety Authority should provide a focus for input from industry, labour, education, and the public.

The risks to health and safety in mining, illustrated by the sad experience in the uranium mines and the perennial list of accidents and injuries, are higher than in most sectors of industry. In underground mining especially the risks are intrinsic to the nature of the endeavour. With respect to fatalities in underground mining the recent record of the industry has been favourable compared to that in several comparable jurisdictions, but the experience of different companies here and in other aspects of injury and disease is quite varied. The Commission considers that the training of workers deserves special attention throughout the industry and that the internal responsibility-system for the performance of work in each company deserves review in the light of the over-all findings of the Commission.

The acceptable levels of risks at work and in life-style are being redefined by society. It is essential that this process be marked by a higher measure of openness than has hitherto characterized government and industrial policy. Openness, contributive participation by workers, and thorough accountability can re-establish the self-regulatory character of the internal responsibility-system at the company level as the key to the control of risks at work in a technologically complex future. The regulatory and auditing functions of the Occupational Health and Safety Authority should be designed to keep the internal system at the company level alert and responsive and to deal bluntly with the true offender.

The Commission believes that the objective of a sound balance between self-regulation and legal compulsion based on the constructive co-operation of all parties cannot be achieved within current government policy and traditional industrial practices. It has formulated its recommendations to promote the change it considers necessary for the future well being of the workers in the mines and plants.

1 Marc Lalonde, *A New Perspective on the Health of Canadians*, Ministry of National Health and Welfare, Canada, Ottawa, April 1974

2 *The Industrial Safety Act, 1971*, Statutes of Ontario, 1971, Chap. 43, as amended by 1972, Chap. 122, and Ontario Regulation 259/72.
3 *The Construction Safety Act, 1973*, Statutes of Ontario, 1973, Chap. 47, and Ontario Regulation 419/73.
4 While the inspectors under the Construction Safety Act in the Ministry of Labour inspect major construction sites throughout the province, they are precluded (see CSA, s. 3(b),6) from inspecting construction on property owned by mines, which includes all the normal surface structures of mines and plants. In steel plants the inspectors under the Mining Act are responsible for inspecting operations extending from the ore unloading docks up to the pouring of pig iron from blast furnaces. The inspectors under the Industrial Safety Act inspect the remainder (see *Memorandum Regarding Jurisdiction of the Department of Labour and Department of Mines*, 13 Nov. 1964). The mining inspectorate has, to the Commission's knowledge, had no professional staff of its own specializing in construction and metallurgical processes.
5 Relations between the Industrial Safety Branch of the Ministry of Labour and the Occupational Health Protection Branch of the Ministry of Health has in the past been guided by a *Memorandum of Agreement* (1 March 1971). A similar Memorandum of Agreement between the then Environmental Health Services Branch of the Ontario Department of Health and the Mines Inspection Branch of the Ontario Department of Mines was drafted in 1969 but never endorsed. A broader interministerial accord between the Ministries of Labour, Natural Resources, Environment and Health on the subject of roles in occupational and environmental health was prepared and endorsed in 1975. This internal accord defines the intended roles of the ministries as regards standards, inspection, environmental monitoring, medical surveillance, records, and research in relation to occupational and environmental health as distinct from safety. This accord does not as such provide a legal mandate for an Occupational Health and Safety Protection Authority. It attempts to deal with the problems of jurisdictions in the operations of ministries by administrative means.
6 *The Public Health Act*, Revised Statutes of Ontario, 1970, Chapter 377 as amended 1971, Chapter 95 (February, 1972), Sections 4 (d), 5 (2), (3), 85, 86 (g), (l).
7 There is a Labour Safety Council consisting of persons representing labour, the accident prevention associations under the Workmen's Compensation Act, and government. The Council advises the minister of labour on changes it deems desirable in the provisions of safety legislation under the jurisdiction of the Ministry. It has commissioned reviews of literature on accidents and published reports and papers (see chap. 4, n. 1). However, it is basically a consultative and advisory body. The new Advisory Committee on Occupational and Environmental Health, which advises the minister of health, is complementary to the Labour Safety Council. Representatives of labour sit on both councils. The Occupational Health Protection Branch in the Ministry of Health as a branch with operational resources has no 'safety' counterpart in the Ministry of Labour.
8 *Health and Safety at Work etc. Act 1974*, Chap. 37, London: HMSO, 1975, s. 21, 22
9 See ibid. and *Safety and Health at Work*, Report of the Committee 1970–72, Chairman Lord Robens, London: HMSO, 1972. The law in England is based on the Robens report, which examined the problems of fragmentation of jurisdictions in occupational health and safety in the United Kingdon. The chairman, Lord Robens, brought to the study extensive experience in mining, and the resulting Act reflects this fact.
Worker's Protection Act and Worker's Protection Ordinance, Ministry of Labour, Stockholm, Sept. 1974
An Act for the Promotion and Protection of the Health and Safety of Persons Engaged in Occupations, The Occupational Health Act, 1972, Saskatchewan

APPENDIX A: RECOMMENDATIONS

CHAPTER 2: SILICOSIS AND DUST

1 That the Occupational Health and Safety Branch of the province conduct or have conducted and publish on a regular cycle not exceeding five years status reports on the evolution of occupational diseases among miners (p. 32)

2 That the radiological status of silicosis in the dust-exposed population currently employed in the Elliot Lake uranium mines and all other uranium mines be reviewed by the Occupational Health and Safety Branch on a biennial basis for a period of at least ten years (p. 33)

3 That the radiological status of silicosis among the persons on record on the Uranium Nominal Roll be reviewed on a biennial basis for a period of at least ten years (p. 33)

4 That the functional purpose, measuring procedures, and measured results relating to all environmental monitoring at the workplace be made known in understandable language to all affected workers and their representatives by the employer and as appropriate by the Mine Inspection Branch (p. 40)

5 That the Mines Inspection Branch within the Occupational Health and Safety Authority conduct annually, or have conducted by an independent agency, sample measurements at representative workplaces of all

environmental quantities whose values are audited by the branch in carrying out its role (p. 43)

6 That the Occupational Health and Safety Authority publish at least biennially a critical review of its appraisal of environmental conditions at the workplaces in the mines and mineral plants (p. 43)

7 That the legal framework for the health and safety of workers in mines continue to recognize the importance of a significant component of collective self-regulation by industry as a whole achieved through a Mines Health and Safety Association (p. 46)

8 That the Mines Inspection Branch within the Occupational Health and Safety Authority, in consultation with industry and the representatives of workers, prepare, under clearly defined statutory authority, CODES OF PRACTICE applicable to all mines relating to: 1/ the prevention and confinement of dust at each distinctive class of workplace; 2/ the provision of ventilation in the breathing zone of workers that is effective for purposes of protecting health at each distinctive class of workplace (including vehicles) (p. 49)

9 That the management of each mining operation or appropriate part thereof be required under clearly defined statutory authority to prepare and keep updated A SCHEME OF PRACTICE for implementing the foregoing codes (p. 49)

10 That the management be required to appoint a competent person to supervise the over-all operation of the scheme (p. 49)

11 That the Occupational Health and Safety Authority establish by regulation a dust standard for personal exposure to free silica in mine and plant aerosols based on a time-weighted average of respirable dust intensity over a working shift and a stipulated lifetime period of exposure (p. 50)

12 That the dust standard for time-weighted average exposure be established on a statutory basis (p. 50)

13 That the Occupational Health and Safety Authority immediately estab-

lish by regulation an interim threshold limit value (TLV) for the mass of respirable free silica in milligrams per cubic metre (p. 51)

14 That the interim TLV have the status accorded by the Occupational Health and Safety Authority to threshold limit values as issued by the American Conference of Governmental Industrial Hygienists (p. 51)

15 That the Occupational Health and Safety Branch prepare a code of requirements for the gravimetric measurement of dust in all mines suited to determining personal exposure to dust (p. 51)

16 That all steps necessary to render effective a gravimetric standard of dust measurement, including those listed herein, be implemented immediately (p. 51)

17 That to provide a basis for establishing a statutory standard or standards for time-weighted average respirable dust exposure in Ontario mines and plants, the Occupational Health and Safety Branch commission epidemiological research on the relation of the incidence of silicosis and of other pulmonary effects to the structure and quantity of aerosols respired in Ontario mines (p. 53)

18 That where more than one recognized toxic component is present in the aerosols the standard specify how an effective combined exposure limit is to be determined (p. 53)

19 That the existing code of requirements for dust measurement in the uranium mines as issued by the chief engineer of the Mines Engineering Branch remain in force (p. 53)

20 That the system of measurement and reporting being conducted by the Mines Accident Prevention Association continue in operation and be subject to independent monitoring as recommended (p. 54)

21 That the current employees in the Elliot Lake uranium mines who are silicotics or exhibit dust effects (radiographic 4) in their lungs be eligible for a voluntary programme of work adjustment; that this programme be supported by management and unions; and that the Workmen's Compensation Board provide rehabilitative compensation and supportive counselling services to assist the persons involved (p. 57)

22 That Section 53 of the Workmen's Compensation Act be amended as necessary to provide clear entitlement for rehabilitative compensation based on the principle of work adjustment for persons subject to exceptional exposure to environmental hazards at work (p. 57)

23 That any employer who rotates job assignments for workmen with the intent of limiting the occupational exposure of any persons to any hazardous environmental condition be required to obtain the formal approval of the Occupational Health and Safety Branch and to maintain permanent occupational records which clearly define the persons, tasks, locations, hazardous conditions, and time intervals involved (p. 57)

24 That during a programme of personal rehabilitation through work adjustment, and for a minimum period of two years thereafter, the income of the worker be maintained in accordance with the provisions of the Workmen's Compensation Act for full compensation which allow the Board to pay in non-taxable compensation 75 per cent of the difference between the current rate of pay and the rate of pay applicable at the date of entry into the programme (p. 58)

25 That in addition to wage maintenance, the worker in a work adjustment programme be eligible for rehabilitation training allowances as provided for in the Workmen's Compensation Act (p. 58)

26 That, further, the worker be entitled to reasonable costs for medical and personal counselling beyond that provided by the Workmen's Compensation Board, and to reasonable moving, travelling, and related relocation costs when these are applicable (p. 58)

27 That when the lungs of a worker exhibit dust effects and the worker seeks the opportunity through work adjustment to take employment with a new employer, the new employer not be held liable for any disability pension or other costs for silicosis or disease conditions related thereto that may be levied as a consequence of the person becoming a silicotic at a future date (p. 59)

28 That the Occupational Health and Safety Branch commission research on the radiographic records related to Miner's Certificates to assess the relative rate of progression of persons in and out of dust (p. 59)

29 That persons on the Uranium Nominal Roll who exhibit dust effects (radiographic 4) within twenty years of entry into Ontario dust exposure, and who have been employed in dust exposure in the uranium mines for a cumulative interval of five or more years from 1954 to 1975 inclusive, be eligible for rehabilitation assistance under a programme of work adjustment (p. 60)

30 That where there is evidence that the exposure of any person to silica-laden dust has been substantially in excess of established dust guidelines or standards and the person has exhibited dust effects in his or her lungs within twenty years of first exposure to dust in Ontario, the person be eligible for work adjustment rehabilitation assistance (p. 60)

CHAPTER 3: LUNG CANCER AND IONIZING RADIATION IN THE URANIUM MINES

31 That the Atomic Energy Control Board confirm the extent to which thoron gas and its daughter products contribute to the irradiation of the respiratory system and other organs of workers in Ontario uranium mines (p. 68)

32 That the Occupational Health and Safety Authority be given by statute the authority and responsibility to conduct a full and expeditious review of any emergent situation in which the health and safety of workers in mines are believed to be at unexpected risk (p. 78)

33 That the Occupational Health and Safety Branch commission a review of the mortality experience of persons on the Ontario Uranium Nominal Roll on a biennial basis for at least ten years (p. 80)

34 That the Atomic Energy Control Board review the basis for and issue explicit regulations establishing the maximum permissible annual exposure to ionizing radiation for workers in uranium and thorium mines and mills (p. 86)

35 That the regulations for maximum permissible exposure delineate how all significant components of external and internal irradiation are to be accounted for and indicate how total exposure and related dose is to be evaluated (p. 86)

36 That the regulations for maximum permissible exposure and related dose be interpreted in units that can be monitored by practical means in uranium and thorium mines and mills (p. 86)

37 That the Atomic Energy Control Board
1/ have research conducted relevant to current circumstances *a*/ on means for measuring all components of ionizing radiation effective in contributing significantly to the irradiation of the lungs, other organs, and tissues of workers in Ontario uranium and thorium mines and mills; and *b*/ on the spatial and temporal distribution of ionizing radiation and related particulates in these mines and mills;
2/ issue codes of guidance *a*/ for the frequency and location of sampling required to determine both the radiation exposure of individual workers in Ontario mines and mills and the general state of the mine and mill environment; *b*/ for the selection, use, maintenance, and calibration of instruments for measuring ionizing radiation both for the determination of individual exposures and for the monitoring of the general mine and mill environment; *c*/ for the identification of persons for whom records of radiation exposure should be kept; and *d*/ for the form, preservation, and use of occupational records for exposure to all significant components of ionizing radiation;
3/ facilitate, with the assistance of the federal Department of Health and Welfare, epidemiological research on a national basis (p. 86)

38 That the Province of Ontario, through the Occupational Health and Safety Authority, establish by statute a standard for maximum permissible annual exposure to ionizing radiation for workers in uranium and thorium mines and mills, and that this standard be in conformity with the regulatory standards of the Atomic Energy Control Board (p. 87)

39 That the Occupational Health and Safety Branch be assigned by provincial statute the responsibility to direct:
1/ the establishment and review of occupational health records for workers in uranium and thorium mines and mills, for regulatory and epidemiological purposes;
2/ the preparation of a code of practice for the sampling and measurement of ionizing radiation in a manner suited to the determination of the exposures of individual workers in uranium and thorium mines and mills and that this code of practice be in conformity with the code of guidance issued by the Atomic Energy Control Board (p. 87)

40 That the Mines Inspection Branch prepare regulations defining the kinds and frequencies of measurements of ventilation, dust and radiation necessary to enable it to audit the engineering operational characteristics of uranium and thorium mines and mills (p. 88)

41 That these regulations be in conformity with the related code of guidance established by the Atomic Energy Control Board (p. 88)

42 That the Occupational Health and Safety Authority specify
1/ a level of radiation in mine or mill air measured at any time in any occupied workplace which, if exceeded, requires that corrective action be taken immediately
2/ a level of radiation in mine or mill air measured at any time in any occupied workplace which, if exceeded, requires closure of the related workplace until the level of radiation is reduced below that specified in 1 (p. 88)

43 That the Occupational Health and Safety Branch commission a study of the mortality experience of the Ontario Uranium Nominal Roll relative to appropriately matched sample populations of non-uranium miners and non-miners in Ontario (p. 91)

44 That the Occupational Health and Safety Authority of the province, in collaboration with the Atomic Energy Control Board, have conducted further epidemiological research based on the exposure to ionizing radiation among Ontario uranium miners (p. 96)

45 That the epidemiological research include a study of 1/ the amount and type of exposure effective in raising cancer mortality, 2/ the pathology of lung cancer in miners, and 3/ the effects of cigarette smoking and of other conjoint occupational factors (p. 96)

46 That persons who work in exposure to ionizing radiation in uranium mines cease smoking both at home and at work for their own sakes and in consideration of their families (p. 96)

47 That each uranium mine install a central monitoring system for its ventilation network to monitor air flow and air quality as indicated by dust, radiation, and other contaminants (p. 102)

48 That the Mines Inspection Branch audit the engineering records of performance of mine ventilation systems (p. 102)

49 That job rotation within mines conducted to meet the standard for maximum permissible annual exposure to ionizing radiation be permitted only in exceptional circumstances with the explicit approval on a case-by-case basis of the Occupational Health and Safety Branch and with the knowledge of the representatives of the workers (p. 105)

50 That records of personal exposure to ionizing radiation maintained by the mines be keyed to Miner's Certificate numbers in sequence and to social insurance numbers in sequence and arranged in a format that facilitates linking to the Mining Master File (p. 107)

51 That the frequency of regular radiographic examination of dust-exposed mine workers be reduced to once every two years unless a radiographic change was apparent at the last examination (p. 107)

52 That tests using sputum cytology be conducted every two years on all persons who have worked in radiation exposure at the uranium mines for five or more years (p. 108)

53 That the Workmen's Compensation Board of Ontario, in collaboration with other provincial boards as provided for in interprovincial agreements, seek out and advise the families of all ascertained deaths due to lung cancer on the Nominal Roll that a claim for compensation should be entered (p. 109)

CHAPTER 4: ACCIDENTS AND INJURIES

54 That the Workmen's Compensation Board require and make provision for the inclusion in non-fatal injury statistics of all non-fatal injuries in which the injured person fails to return to his or her regular job on the day following the date of the accident giving rise to the injury (p. 121)

55 That management inform the Joint Health and Safety Committee about its policies on rehabilitative work assignment and in the context of independent medical consultation seek the advice of the Committee in giving wise effect to its policies (p. 121)

56 That the Mines Inspection Branch base its patterns of audits in part on studies of the relative risks involved in different segments of mining operations and on the related man-years at risk (p. 128)

57 That the Occupational Health and Safety Branch publish biennially a critical review of factors that influence risks of accident and injury at workplaces in the mines and mineral plants (p. 130)

58 That the Occupational Health and Safety Authority, in consulation with the Workmen's Compensation Board, industry, and labour, review the procedures for the reporting of injuries and accidents with a view to establishing links to occupational records and thereby facilitating accident research by sample methods (p. 145)

59 That the senior management of each mining operation review the performance of its internal responsibility-system, placing special emphasis on the delineation of 1/ responsibility to detect and to report departures from standard conditions at every level of operations, 2/ location of responsibility for ensuring that identified departures are dealt with, 3/ procedures for committing the resources to correct anomalies, and 4/ procedures for checking the action already taken and still to be taken (p. 152)

60 That statutory provision be made for the appointment in each mine and plant of worker-auditors having the authority and responsibility to examine and report upon conditions of work pertaining to the health and safety of workers at sets of workplaces designated by management in such a way as to encompass all workplaces in underground, open pit, reduction plant, and shop and surface operations (p. 153)

61 That worker-auditors be given released time with regular wages while performing their duties (p. 154)

62 That the Workmen's Compensation Act be amended to make provision for the assessment of the costs of worker-auditors upon employers in class 5 (p. 154)

63 That worker-auditors be appointed from among qualified candidates for a period of three years through the collective bargaining unit, where such exists, or be elected by the workers (p. 155)

64 That there be statutory provision for the appropriate worker-auditor to participate in the investigation of fatal accidents and serious injuries (p. 156)

65 That the designated worker-auditor have the privilege of cross-examining witnesses at an inquest into any fatal accident whose circumstances he has participated in investigating (p. 156)

66 That there be statutory provision for the establishment of a Joint Labour-Management Health and Safety Committee at each mine and plant (p. 157)

67 That the membership of the Committee consist of equal numbers of persons appointed by management and appointed by members of the collective bargaining unit(s), where such exist, and otherwise elected by the workers collectively, subject to the constraint that at least two of the persons selected be worker-auditors (p. 157)

68 That the Joint Committee conduct its work as far as feasible during regular hours of work and that its members receive their regular wages while engaged on committee work (p. 157)

69 That the Joint Committee meet regularly at least four times per year and not more often than once monthly (p. 158)

70 That each mining company provide its employees with a written statement outlining its policy for health and safety and the organizational arrangements and responsibilities for giving effect to it (p. 160)

71 That the core of the staff of the Mines Inspection Branch continue to be based on persons of exceptional professional experience in mining, and related fields of engineering, supplemented by special training in occupational health and safety and in the principles of the administration of work (p. 163)

72 That task groups set up by the Occupational Health and Safety Authority to advise on codes of practice and statutory regulations relating to technological change in mining include representatives of labour (p. 163)

73 That the industry, government, and labour give high priority to the development, standardization, and accreditation of modular training and qualification for workers in mines and plants (p. 169)

74 That persons assigned to work alone be required to have specified qualifications for independent work at the job to which they are assigned (p. 174)

75 That on all shifts persons working alone be visited at the place of work at least three times (other than at the start of a shift) by a first-line supervisor (p.174)

76 That such visits may be reduced to once per shift (other than at the start of a shift) if 1/ work conditions are standard, and 2/ means of communication are provided and a record of use thereof is kept so that the person working alone reports his status to a point of supervision or to a designated fellow worker not less often than once every two hours (p. 174)

77 That where the location of work is sufficiently remote to warrant the use of technical means of communication and where no illumination other than that of the miner's cap lamp is normally available, an auxiliary source of illumination powered by means other than the miner's lamp battery be provided at the workplace (p. 175)

78 That all fatalities and serious injuries to persons working alone underground be the subject of biennial review by the Occupational Health and Safety Branch (p. 175)

79 That section 169(16)(b) be amended (and be included in a revised Act, to be recommended) to require the supervisor to make a written report which: 1/ states the nature of the condition of the machine or device which in the worker's belief renders it unsafe for use; 2/ gives the supervisor's comments at the time; and 3/ gives the supervisor's confirmation or otherwise that section 169(15) is, in the supervisor's view, satisfied (p. 176)

80 That the worker who refers a machine or device to his supervisor under section 169(16)(b) as amended sign and receive a copy of the supervisor's report (p. 177)

81 That where a worker after due consultation with his immediate supervisor, believes that the work then assigned cannot be performed by standard procedures without encountering personal risks deemed by him to be unreasonable, there be a statutory requirement that the work situation be examined and judged by a member of senior supervision in the presence of a worker-auditor acting as an observer and that a report of the circumstances be made to the mines inspectorate by the manager (p. 178)

CHAPTER 5: OTHER ENVIRONMENTAL HAZARDS AT THE WORKPLACE

82 That there be a statutory requirement for a metallurgical audit of origin, holdup, and destination of potentially dangerous minor elements such as lead, mercury, arsenic, selenium, tellurium, cadmium, and antimony to be conducted quarterly in all reduction plants on the basis of extended standard monthly sampling and analytical procedures, and that a copy of this audit be sent to the Occupational Health and Safety Authority (p. 200)

83 That there be a statutory requirement for an annual audit of use by mass of toxic and hazardous reagents and that a copy be sent to the Occupational Health and Safety Authority (p. 200)

84 That pilot plant studies used to develop processes and preliminary operating procedures be extended to include the measurement of factors likely to have an impact on the health and safety of the environment for work (p. 200)

85 That there be a statutory requirement for each mining company to maintain a register of servicing chemicals involved in any personal encounter associated with a medical aid or compensable injury; that the register specify both trade name and chemical composition and identify all known toxic chemical constituents; that the register include an audit by mass of annual use; and that a copy of this register be provided to the Occupational Health and Safety Authority (p. 204)

86 That there be a statutory requirement for each mining company to give the Occupational Health and Safety Authority notice of intent to intro-

duce any new reagent or servicing chemical whose toxic characteristics are not known (p. 204)

87 That with respect to codes of practice and schemes of practice the principles of recommendations 8, 9, and 10 be extended 1/ to the maintenance and operation of mills and metallurgical plants as these activities relate to the leaking and spilling of toxic substances and hot materials into workplaces; 2/ to the handling and use of reagents and servicing chemicals and to the consequences of their leaks and spills (p. 204)

88 That engineering schools review and redefine their responsibility to the profession to ensure that graduates are more keenly aware of and responsive to the impact of technological design upon the occupational health and safety of workers (p. 205)

89 That resources for joint research and teaching by specialists in occupational health and safety in faculties of medicine and engineering be given high priority by both the universities and government (p. 205)

90 That profiles of risk-encounter for toxic substances be developed by examining the work patterns of maintenance workers, and that modular training be adapted to such profiles (p. 206)

91 That at any location of regular work where acute encounters with toxic substances repeatedly occur as a result of leaking, recirculating, or spilling from metallurgical and milling processes, there be a statutory requirement for the installation and use of equipment for the continuous monitoring of the substances involved (p. 206)

92 That a record of the substances and human effects of acute encounters with toxic substances leading to medical aid and compensable injuries be maintained in the occupational health records of each worker at the company level (p. 207)

93 That at five-year intervals the Occupational Health and Safety Branch commission a review of the status of the health of samples of persons who are at high risk from acute encounters with toxic substances, including as necessary intensive medical surveillance (p. 207)

94 That epidemiological reviews of selected populations subject to chronic exposure to toxic substances in reduction plants and mines matched to suitable control groups be conducted on a five-year cycle by or under the guidance of the Occupational Health and Safety Branch and that the essential results of such studies be summarized and published upon completion (p. 212)

95 That a nominal roll of workers at risk of exposure to nickel carbonyl in reduction plants and pilot plants be established by the Occupational Health and Safety Authority, in co-operation with the industry and that the morbidity and the mortality experience of this nominal roll be reviewed at least every five years (p. 213)

96 That the appropriate substance or intent of recommendations 8, 9, 10, 39(2), 40, 42, and 46 be made applicable to asbestos mines and plants (p. 215)

97 That the Occupational Health and Safety Authority establish, with the co-operation of the Workmen's Compensation Board and the mining industry, a nominal roll of all persons who have worked one or more months in exposure to asbestos dust in asbestos mines and plants (p. 215)

98 That the Occupational Health and Safety Branch commission a review of the radiographic record and of the mortality experience for the asbestos nominal roll on a five-year cycle (p. 215)

99 That workers in reduction plants who have been exposed for twenty years or longer to sulphur dioxide at levels approaching the current Threshold Limit Value and to associated dust and fumes, and who exhibit the clinical diagnosis of chronic bronchitis and impaired pulmonary function as identified by objective tests, be considered for compensation at up to a maximum of 20 per cent disability (p. 219)

100 That the Occupational Health and Safety Authority, in co-operation with the industry and labour, prepare a code of requirements for diesel emissions (p. 222)

101 That the Mines Inspection Branch prepare a code of practice for the provision of ventilation and for the fuelling, operation, and maintenance of diesel engines (p. 222)

102 That each mine using diesel equipment be required to file with the Mines Inspection Branch a scheme of practice for the short-term and long-term maintenance of its diesel engines (p. 222)

103 That each mining operation maintain noise maps based on full-scale conditions of operation which delineate all areas of work at which the noise level is 85 dB(A) or higher (p. 229)

104 That the mining industry, in co-operation with labour and the Occupational Health and Safety Authority, have conducted research to determine shift-profiles of noise encounter for representative occupations in mines and plants both in the absence and in the presence of actual and best-available hearing protection, that such profiles be codified and published, and that a code be assigned to each worker who regularly encounters areas of work in which noise levels of 85 dB(A) or higher exist (p. 230)

105 That the mining industry and equipment manufacturers, with the Canadian Standards Association, expedite the development of standards for the assessment of noise from mining equipment, and for the performance of personal safety equipment and cab enclosures in attenuating noise, and that such standards be invoked by the industry in specifying noise performance requirements for new equipment (p. 230)

106 That the Occupational Health and Safety Authority issue a code of practice for the selection and use of personal hearing protection and for communicating in the presence of noise (p. 231)

107 That, by statute, each mining company be made responsible for maintaining effective audiometric records for each employee who in the absence of hearing protection regularly encounters noise at levels of 85 dB(A) or higher, and that such audiometric records be required to be keyed 1/ to social insurance numbers, 2/ to Miner's Certificate numbers where such have been assigned, and 3/ to a code number of noise-profile-encounter as previously recommended (p. 232)

108 That the Occupational Health and Safety Branch commission on a five-year cycle statistical assessments of the state of hearing among sample populations of workers in mines, and that the first review be of production crews in underground operations, including diesel operators (p. 232)

109 That the Occupational Health and Safety Branch regularly inspect all audiometric testing facilities not under the supervision of a designated medical specialist, and that any designated medical specialist be required to certify biennially in writing that the facilities under his supervision conform to the minimum standards of the Branch as then current (p. 233)

110 That the Occupational Health and Safety Authority be assigned by statute the responsibility to establish standards or guidelines for personal exposure to all toxic substances and hazardous physical agents and that, subject to any statutory standards and in consultation with industry and labour, the Authority issue a code of practice for the application in mines and plants of the Threshold Limit Values of the American Conference of Governmental Industrial Hygienists (p. 235)

111 That the mining industry establish for its employees, where such is not now provided, occupational health surveillance by a supervising medical director or consultant experienced in occupational medicine (p. 237)

112 That the labour unions individually or in consort appoint to their staff a consulting specialist in occupational medicine (p. 237)

113 That under the Workmen's Compensation Act provision be made for the levying on all employers in class 5 an amount of 0.03 per cent of wages currently subject to levy under the Act to create a fund for research on occupational health and safety by the joint labour-management health and safety committees (p. 239)

CHAPTER 6: POLICY FOR OCCUPATIONAL HEALTH AND SAFETY IN THE MINING INDUSTRY

114 That a Health and Safety in Mines and Plants Act, separate from the Mining Act, be prepared to replace part IX and the relevant sections of part XI of the Mining Act and be administered within an Occupational Health and Safety Authority established in the Ministry of Labour (p. 254)

115 That the Health and Safety in Mines and Plants Act consist of a core of

general provisions supplemented by regulations the issuance of which is authorized by the Act (p. 254)

116 That the general provisions of the Health and Safety in Mines and Plants Act identify the duties and responsibilities of the Mines Engineering and Inspection Branch and the Occcupational Health and Safety Branch (p. 254)

117 That an Occupational Health and Safety Authority, encompassing the Mines Engineering and Inspection Branch, the corresponding branches under the Industrial Safety Act and the Construction Safety Act, and the Occupational Health and Safety Branch, be established in the Ministry of Labour under an assistant deputy minister (p. 254)

APPENDIX B: BRIEFS AND PRESENTATIONS BEFORE THE COMMISSION

	Brief	Organization	Transcript pages	Exhibit
Elliot Lake				
Jan. 14/75	1	Mines Accident Prevention Association of Ontario	6–216	1 Tables and graphs from brief submitted by Mines Accident Prevention Association dated Jan. 14/75. 2 Appendix to brief submitted by Mines Accident Prevention Association of Ontario.
Jan. 14/75	2	Mrs Cecile Tellier, Individual	216–22	
Jan. 14/75	3	Mr J. Roch, President, Local 5417, United Steelworkers of America	223–40	3 Appendices A and B of brief presented by Mr Joe Roch, Local 5417, United Steelworkers of America.
Jan. 14/75	4	Mr Harvey Saumier, Recording Secretary and Chairman of Compensation Committee, Local 5417, United Steelworkers of America, Elliot Lake	244–64	4 Xerox copy of Globe and Mail article of June 7/74, presented by Mr H. Saumier, Local 5417, United Steelworkers of America.
Jan. 14/75	4A	Mr. R. Boreham, Individual	264–8	
Jan. 14/75	5	Mr Gus Frobel, Individual	268–93	5 List of Appendices submitted by Mr G. Frobel, Local 5417, United Steelworkers of America.

Jan. 14/75	6	Mr Ruben Juuti, Individual	293–9	
Jan. 14/75	7	Mr P. Markert, Individual	300–5	
Jan. 15/75	8	Mrs Mavis Boreham, Individual	307–16	
Jan. 15/75	9	Rio Algom Mines Ltd	316–545	6 Appendices and charts in brief submitted by Rio Algom Mines. 7 Volume of training Appendices submitted by Rio Algom Mines.
Jan. 15/75	10	Mr R. Portelance, Trustee, Local 5762, United Steel-workers of America, Elliot Lake	545–55	
Jan. 15/75	11	Mr G. Labelle, Individual	556–63	
Jan. 15/75	12	Mr E. Vance, President, Local 5762, United Steel-workers of America	563–78	
Jan. 15/75	13	Mr Richard Cayen, Individual	578–82	
Jan. 15/75	14	Mr C. Barrett, Individual	582–9	
Jan. 15/75	15	Mr G. Seguin, Member Safety and Compensation Committee, Local 5417, United Steelworkers of America	589–98	

	Brief	Organization	Transcript pages	Exhibit
Elliot Lake (continued)				
Jan. 16/75	16	Mr D. Mellor, (speaking on behalf of B. Young, appointed Vice-President of Union) Local 5762, United Steelworkers of America	602–11	
Jan. 16/75	17	Denison Mines Ltd	611–832	8 Figures 1–5 of brief submitted by Mr de Bastiani of Denison Mines.
				9 Appendices A to O of brief submitted by Denison Mines.
				10 Map of Denison Mines showing ventilation as of Jan. 16/75.
				11 Folder containing 3 photographs of equipment in Denison Mines.
				12 Copy of Agreement between Denison Mines Ltd and the United Steelworkers of America dated Jan. 1/73.
				13 Prescription from Elliot Lake Medical Centre dated Jan. 10/69, submitted by Mr de Bastiani of Denison Mines.

Jan. 16/75	18	Professor R.W. Thompkins (presented as part of Denison Mines brief)		
Jan. 16/75	19	Mr J Scott, Representative, Local 5980, United Steel-workers of America	833–37	14 Drawing of Heating Unit in Denison Mine, presentedby John Scott, Local 5980, United Steel-workers of America.
Jan. 16/75	20	Mr R. Beaudin, Individual	837–42	
Jan. 16/75	21	Mr C. Beaulieu, Individual	842–4	
Jan. 16/75	22	Mr R. Fox, Individual	844–9	
Jan. 16/75	23	Mr C. Kados, Individual	849–53	
Jan. 17/75	24	Mr A. Maas, Individual	856–60	
Jan. 17/75	25	Mr S. Taylor, Chairman, Safety and Health Committee, Local 5762, United Steel-workers of America	861–930	15 Appendices A to I attached to brief from Mr Taylor, Local 5762, United Steelworkers of America.
				16 Bag of dust and several filters from a series of masks, submitted by Mr S. Taylor, Local 5762, United Steelworkers of America.
Jan. 17/75	26	Mr K.A. Valentine, Education and Welfare Dept. National Office, Toronto, United Steelworkers of America	932–95	17 Extract from Canadian Mining Journal, Feb. 1974, submitted by K. Valentine, National Office United Steelworkers of America.

	Brief	Organization	Transcript pages	Exhibit
Elliot Lake (continued)				
				18 Proforma of licence issued by Atomic Energy Control Commission, submitted by K. Valentine, National Office, United Steelworkers of America.
				19 Regulation issued April 13/60, by Atomic Energy Control Board, submitted by K. Valentine, National Office, United Steelworkers of America.
				20 Regulation dated June 4/74, of Atomic Energy Control Board, submitted by K.A. Valentine, National Office, United Steelworkers of America.
Jan. 17/75	27	Mr G.H. Gilchrist, Area Supervisor for Northeastern Ontario, United Steelworkers of America Union	995–1008	21 Convention concerning the Protection of Workers against Ionizing Radiations, Conv. #115, from International Labour Conference 1960, submitted by Mr G. Gilchrist, United Steelworkers of America.

				22 Recommendation from International Labour Organization Conference of 1974, submitted by Mr G. Gilchrist, United Steelworkers of America.
				23 Document entitled 'Radon gas and pneumoconiosis, silicosis and uranium miners,' *Steel Labour*, March 1973, submitted by Mr G. Gilchrist.
				24 Article from *Steel Labour*, Jan. 1971, concerning Mr Gus Frobel and other pertinent information submitted by Mr G. Gilchrist.
				25 Copy of *Steel Labour*, April 1974, submitted by Mr G. Gilchrist.
				26 Two booklets published by Ontario Department of Mines, 1961 – 'Accidents and related representations,' and 'Accident review, ventilation ground control and related subjects,' submitted by Mr G. Gilchrist.
Jan. 17/75	28	Mr O. Hamel, Individual	1010–12	
Jan. 17/75	29	Mr E. Bernatchez, Individual	1012–14	

	Brief	Organization	Transcript pages	Exhibit
Red Lake				
Jan. 20/75	30	Mr G. Prest, President, Local 950, United Steelworkers of America	1017–47	
Jan. 20/75	31	Dickenson Mines Ltd	1047–1137	27 Appendices 1, 2, and 3 of Dickenson Mine brief submitted by Mr D.C. Rance, Mine Manager.
				28 Safety booklet from Dickenson Mine, submitted by Mr D.C. Rance.
				29 Proforma of Injury Report Form of Dickenson Mine, submitted by Mr D.C. Rance.
Jan. 20/75	32	Griffith Mine	1138–76	30 Attachments 1, 2, and 3 of Griffith Mine brief submitted by Mr J.D. Jeffries, Mine Manager.
				31 Copy of publication 'Target Zero' by Pickands Mather and Co., submitted by Mr J.D. Jeffries, Mine Manager.
				32 Copy of Griffith Mine Safety Recommendation Form submitted by Mr J.D. Jeffries, Mine Manager.

Jan. 20/75	33	Mr D. Gustin, President, Local 7020, United Steelworkers of America	1176–82	
Jan. 21/75	34	Campbell Red Lake Mines	1212–20	33 Sections 2 and 3 of brief of Campbell Red Lake Mines, submitted by Mr G.E. Peacock and Mr S. Reid.
	34A	Mr H. Koop, President, Local 5672, United Steelworkers of America	1220–50	
Jan. 21/75	35	Mr D. Posnick, Staff Representative, District #6, Winnipeg, United Steelworkers of America	1250–1301	
Thunder Bay				
Jan. 22/75	36	Steep Rock Mines Ltd	1305–49 1410–14	34 Appendices A, B, C, and D to brief presented by Steep Rock Iron Mines Ltd.
Jan. 22/75	37	Mr A.J. Lavoie, Staff Representative, District 6, United Steelworkers of America on behalf of Locals 3466, 5855, 7520, 7879, 8126, United Steelworkers of America	1350–70	

	Brief	Organization	Transcript pages	Exhibit
Thunder Bay (continued)				
Jan. 22/75	37A	Mr H. Gareau, Staff Representative, District 6, United Steelworkers of America	1370–84	35 Document entitled 'Information supporting oral presentation to the Royal Commission on the Health and Safety of Workers in Mines,' submitted by Mr H. Gareau, Staff Representative of United Steelworkers of America.
				36 Two letters, one addressed to Dr Johnson from Mr H. Gareau dated Oct. 31/74, and reply from Workmen's Compensation Board dated Nov. 15/74.
Jan. 22/75	37B	Mr A.A. O'Neil, President, Local 3466, United Steelworkers of America	1384–93	37 Series of photographs at Steep Rock Mines submitted by Mr A.A. O'Neill, President of Local 3466, United Steelworkers of America.
Jan. 22/75	37C	Mr J.F. Wilson, Vice-President, Local 5855, United Steelworkers of America	1393–1403	
Jan. 22/75	37D	Mr L. Fraser, President, Local 7879 United Steelworkers of America	1403–10	38 Copies of minutes of five Management/Union Safety Committee meetings submitted by Mr L. Fraser,

					Local 7879 of the United Steelworkers of America at Mattabi Mines.
Jan. 22/75	38	Mattabi Mines	1414–54	39	Copy of Notice entitled 'Safe working conditions,' posted at Mattabi Mines, submitted by Mr J.C. White, Manager.
Jan. 22/75	39	Mr M.C. Sheppard, Individual	1454–65		
Jan. 23/75	40	Noranda Mines Limited (Geco Division)	1467–1523	40	Several general Safety Rule pamphlets for Noranda Mines (Geco Division) submitted by Mr E. Brooks, Mine Manager.
				41	Minutes of Management/Union Safety Committee meetings and Crew Safety meetings of Noranda Mines (Geco Division) submitted by Mr E. Brooks, Mine Manager.
Jan. 23/75	41	Mr A. Corey, Individual	1524–8		
	42	Mr A.J. Lavoie, Staff Representative, District 6, United Steelworkers of America	1528–33	42	Letter addressed to E. Murray signed by A.J. Lavoie, dated May 10/74, submitted by A.J. Lavoie.
				43	Reply from Mr Murray to Mr Lavoie dated June 4/74, submitted by Mr A.J. Lavoie.

	Brief	Organization	Transcript pages	Exhibit
Thunder Bay (continued)				
Jan. 23/75	42A	Mr H. Gareau, Staff Representative, District 6, United Steelworkers of America	1533–35	
Sault Ste Marie				
Jan. 24/75	43	Mr P. Krmpotich, Staff Representative, United Steelworkers of America, Sault Ste Marie and area	1539–57	
Jan. 24/75	44	Mr P. White, Chairman, Compensation, Safety and Health Committee, Local 2251, United Steelworkers of America	1558–69	
Jan. 24/75	45	Mr L.C. Woodcock, Staff Representative, United Steelworkers of America, Sault Ste Marie	1569–1614	
Jan. 24/75	46	Mr D. McLean, President Local 3933, United Steelworkers of America, Wawa	1615–43	43A Diagnosis dated 1973 and letter from Workmen's Compensation Board to Mr Joseph Zilys dated

					April 9/74, submitted by Mr D. McLean.
Jan. 24/75	47	Algoma Ore Division of Algoma Steel	1643–92	44	Appendices 1–6 of Algoma brief submitted by Mr R. Turpin.
				45	Algoma Rotating Safety Slips, Safety Reminder Cards.
Sudbury					
Jan. 27/75	48	Mr R.C. White, Vice-President, Local 5500, United Steelworkers of America	1697–1709		
Jan. 27/75	49	Mr J.L. Gagnon, Chairman, Sintering Plant Action Committee, Local 6500, United Steelworkers of America	1710–56	46	Brief prepared for the Hon. M. Starr and the Workmen's Compensation Board re the Sintering Plant dated Nov. 7/73, submitted by Mr J.L. Gagnon.
Jan. 27/75	50	Mr C. Lambert, Chairman, Safety and Health Committee, Local 6500, United Steelworkers of America	1756–2003	47	Reported accidents in the operation of the International Nickel Co. covering the period Sept. 1970 to Aug. 1971 and Aug. 1971 to July 1972, submitted by Mr C. Lambert.
				48	Reported accidents in the operation of the International Nickel Co. covering the period Aug. 1972 to July 1973, submitted by Mr C. Lambert.

	Brief	Organization	Transcript pages	Exhibit
Sudbury (continued)				
				49 Reported accidents in the operation of the International Nickel Co. covering the period Aug. 1973 to July 1974, submitted by Mr C. Lambert.
				50 Fatalities at INCO 1964–73, submitted by Mr C. Lambert.
				51 Copy of brief concerning safety of miners working in Sudbury area prepared in Aug. 1973 and submitted by Local 6500, United Steelworkers of America.
				52 Supplementary pages in Mr C. Lambert's brief.
Jan. 28–9/75	51	International Nickel Co. of Canada	2003–2258	53 INCO – yellow-covered book entitled 'Basic safety for new employees,' submitted by Mr C. Hews.
				54 INCO – bundle of blue-covered Reminder Cards, submitted by Mr C. Hews.
				55 INCO – *All Mines Standard Practice, 1971 Revision*, submitted by Mr C. Hews.
				56 Two booklets – *Conservation of*

					Hearing in Nickel Mining Industry by Dr V.F. Hazelwood and *Audiometric Test Program*, INCO, presented by Mr C. Hews.
Jan. 29/75	52	Falconbridge Nickel Mines (Sudbury Operations)	2259–2361	57	Appendices of brief submitted by Falconbridge Nickel Mines and presented by Mr A. Baker, Assistant General Manager of Sudbury operations.
Jan. 29/75	53	Mr E. Nitchie, President, Local 598, Mine, Mill, Smelter Workers Union	2361–80		
Jan. 29/75	54	Mr R.J. Thomson, President, Local 6855, United Steelworkers of America	2380–99		
Jan. 30/75	55	Ontario Mining Contractors	2401–12	58	Two graphs from Ontario Mining Contractors submitted by Mr F. Walker.
Jan. 30/75	56	Mr G.H. Gilchrist, Area Supervisor, Northeastern Ontario, United Steelworkers of America	2412-63	59	Appendices to brief of United Steelworkers of America presented by Mr G. Gilchrist and copies of extract from *Sudbury Star* newspaper.
Jan. 30/75	57	Mr A. Robineau, Individual	2464–70		
Jan. 30/75	58	Mr K. Mersel, Co-Chairman Safety & Health Committee, Local 6500, United Steelworkers of America	2470 90	60	Supplementary material presented by Mr K. Mersel, further to United Steelworkers brief submitted by Mr G. Gilchrist.

Date	Brief	Organization	Transcript pages	Exhibit
Timmins (continued)				
				67 Air volume statistics – charts and graphs – 2 pages, Compensable Accident Frequency (chart) Appendix A – Crew Safety meetings – submitted by Mr A. Adamson.
Jan. 31/75	66	Mr L. Lachapelle, President, Local 4462, United Steelworkers of America	2646–59	
Jan. 31/75	67	Pamour Porcupine Mines Ltd	2659–2706	
Jan. 31/75	68	Mr D. Smith, President, Local 7267, United Steelworkers of America	2706–16	
Jan. 31/75	69	Mr L. Magnuson, President, Local 7580, United Steelworkers of America	2716–22	
Jan. 31/75	70	Dome Mines Ltd	2722–74	68 Letter, dated Oct. 29/66, to United Steelworkers. Diagrammatic sketch of ventilation flow series, submitted by Mr H.V. Pyke, Manager, Dome Mines Ltd.
				69 Safety Manual, Dome Mines Ltd, submitted by Mr H.V. Pyke.

Jan. 31/75	71	Mr L. Carignan, President, Local 8091, United Steel-workers of America	2774–88
Jan. 31/75	72	Mr H.B. de Gurse, Staff Representative – Area: Raymour to Foliet	2788–1813 2870–1
Jan. 31/75	73	Mr E. Gocholski, Individual	2813–20
Jan. 31/75	74	Mr I.S. Torok, Individual	2820–3
Jan. 31/75	75	Mr H. Rigg, Individual	2823–31
Jan. 31/75	76	Mr N. Quinn, Individual	2831–40
Jan. 31/75	77	Mr W. Fuller, Individual	2840–5
Jan. 31/75	78	Mr J. Gomercich, Individual	2845–52
Kirkland Lake			
Feb. 1/75	79	Mr W. Holmes, Individual	2854–60
Feb. 1/75	80	Mr J. Nadeau, Individual	2860–6
Feb. 1/75	81	Mr R. Ilomaki, Individual	2866–70
Feb. 1/75	82	Mr H. Duncan, President, Local 4440, United Steel-workers of America	2871–4
Feb. 1/75	83	Mr J. Smith, President, Mr W. Reeves, Director of Safety at the Mines, Local 6409, United Steel-workers of America	2878–96

	Brief	Organization	Transcript pages	Exhibit
Kirkland Lake (continued)				
Feb. 1/75	84	Adams Mine	2897–2959	69(1) Appendices A, B, and C to brief submitted by the Adams Mine – Mr John Merrell, District Personnel Manager.
				70 Accident Frequency Report, 1964–74, submitted by Mr J. Merrell of the Adams Mine.
Feb. 3/75	85	Mr D. Hunter, Union Rep., Local 4501, United Steelworkers of America	2960–3003	
Feb. 3/75	86	Mr Huywan, Individual	3003–6	
Feb. 3/75	87	Mr J. Murnaghan, Mr J. Labine, Recording Secretary, Local 4584, United Steelworkers of America	3006–21	
Feb. 3/75	88	Hollinger Mines	3021–57	71 MAPAO Survey of Dust Conditions – dated Jan. 7/75. Hollinger Mines submitted by Mr C.B. Ross, General Manager.
Feb. 3/75	89	Mr B. Kiazyk, Individual	3053–7	
Feb. 3/75	90	Mrs M. MacLeod, Individual	3058–65	72 A file of papers belonging to Mrs M. MacLeod.

Feb. 4/75	91	Kerr Addison Mines	3068–3100		
Feb. 4/75	92	Silverfields, Division of Teck Corporation Ltd	3100–20		
Feb. 4/75	93	Mr L. Fennel, Safety Committee Chairman, Local 6896, United Steelworkers of America	3121–33		
Feb. 4/75	94	Mr F. Pearson, Individual	3133–4		
Feb. 4/75	95	Mr F. Nabb, Individual	3134–5		
Feb. 4/75	96	Mr R.F. Lockhart, Regional Engineer, Ministry of Natural Resources	3136–44		
Feb. 4/75	97	Mr P.S. Oliver, Individual	3144–8		
Toronto					
Feb. 5/75	98	Association of Professional Engineers of Ontario	3151–71	72(1)	The Professional Engineers Act, revised up to 1972. Regulations, By-Laws, Code of Ethics submitted by Mr C.A. Campbell, President of the Association of Professional Engineers of Ontario.
Feb. 5/75	99	McIntyre Research Foundation	3171–3286	73	Appendices to McIntyre Research Foundation submitted by Mr W.B. Dix, President.
				74	*Silicosis, What It Is and How It Can Be Prevented*, McIntyre Research

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				Foundation, submitted by Mr W.B. Dix.
				75 1954 Program of a conference on Silicosis by the McIntyre Research Foundation, submitted by Mr W.B. Dix.
Feb. 5/75	100	Dr. J.W.G. Hannon, Medical Director, McIntyre Research Foundation	3287–3306	
Feb. 5/75	101	Construction Safety Association	3307–21	
Feb. 5/75	102	International Railway Brotherhood	3321–32	
Feb. 5/75	103	Mr E. Martel, Member of the Provincial Legislature for Sudbury East	3332–54	76 Letter of Sept. 17/70, from the Dept. of Mines and Northern Affairs. Letter of July 31/70, from International Nickel and letter of Aug. 25/70, from Local 6500 submitted by Mr Eli Martel, Provincial Member Sudbury East.
				77 A series of letters: – July 7/71 addressed to Mr P. Falkowski from Mr Martel.

- July 7/71 addressed to the Hon. G. Kerr from Mr Martel.
- Memo dated June 25/71 to Mr Martel from Mr G. Kerr.
- July 11/71 addressed to Mr G. Kerr from Mr A.B.R. Lawrence.
- June 2/71 addressed to Mr G. Kerr from Mr A.B.R. Lawrence.
- Memo dated May 27/71 to Mr A.B.R. Lawrence from Mr G. Kerr.
- Memo dated May 20/71 to Mr G. Kerr from Mr G. Hampson.
- Memo dated May 19/71 to Mr G. Hampson from Mr D.S. Caverly.
- May 19/71 to Mr L.E. Grubb from Mr D.S. Caverly.
- April 14/71 to Mr G. Kerr from Mr E. Martel.
- April 2/71 to Mr G. Kerr from Mr P. Falkowski.

78 Letter dated June 15/70 to Mr E. Prudhomme from Mr W.K. Redsell. Letter dated June 15/70 to Mr J.M. Hughes from Mr W.K. Redsell, submitted by Mr E. Martel.

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				
				79 Letter dated April 28/71 to Mr L. Bernier from Mr Martel. Reply dated April 15 to Mr Martel. Letter dated April 15 to Mr Prudhomme from Mr Bernier, submitted by Mr E. Martel.
Feb. 5/75	104	Mr F. Laughren (Member of Provincial Legislature for Sudbury Nickel Belt)	3354–61	
Feb. 17/75	105	Mr L. Williams, Director District 6, United Steelworkers of America	3363–3433 3450–85	80 Booklet entitled 'How the Union Serves,' issued by the United Steelworkers, submitted by Mr L. Williams, Director, District 6, United Steelworkers of America.
				81 Booklet entitled 'Constitution of the International Unit of the United Steelworkers of America,' dated Dec. 27/54, submitted by Mr L. Williams.
				82 Booklet of the Constitution for the United Steelworkers, dated Sept. 20/56, submitted by Mr L. Williams.

83 Extracts of the third and fourth constitutional convention of the United Steelworkers submitted by Mr L. Williams.

84 Summary of proceedings of the United Steelworkers in 1974, submitted by Mr L. Williams.

85 Book with red cover, safety manual for the United Steelworkers dated March 1974, submitted by Mr L. Williams.

86 Book with blue cover entitled 'Recommended Safety & Health Program,' by United Steelworkers, submitted by Mr L. Williams.

87 Document entitled 'Manual of Safety & Health,' Canadian Labour Congress, submitted by Mr L. Williams.

88 Letter to all staff representatives – District 6, signed by L. Sefton, Director, dated Oct. 14/70, with attached material.

89 Copy of a letter dated April 4/74 from Mr Williams, United Steelworkers, with attached printout

Brief	Organization	Transcript pages	Exhibit	
Toronto (continued)				
				material, submitted by Mr L. Williams.
			90	Memorandum signed by Mr Williams dated Oct. 9/74, with attached list of occupations with potential arsenic exposure, submitted by Mr L. Williams.
			91	Folder dated July 1962, INCO Agreement with attached material, submitted by Mr L. Williams.
			92	The original and revised safety and health proposals and the 1966 agreement with INCO submitted by Mr L. Williams.
			93	Document similar to Exhibit 92 relating to the 1969 agreement, submitted by Mr L. Williams.
			94	Document similar to other exhibits relating to the 1972 agreement, submitted by Mr L. Williams.
			95	Copy of submission 'Health and living conditions of Timmins

miners,' Nov. 1954, submitted by Mr L. Williams.

96 Copy of the *Ontario Mineral Review of 1973*, submitted by Mr L. Williams.

97 List headed 'Inspectors employed by Ontario government ministries,' dated Feb. 1974, submitted by Mr L. Williams.

98 Report printed called 'Summer special' dated July 1974, submitted by Mr L. Williams.

99 Chart headed 'Employment fatalities per million hours, mine industry, 1951–1970,' submitted by Mr L. Williams.

100 Paper entitled 'Special report. Labour shortage in mining. The steelworkers' answer to a national problem,' submitted by Mr L. Williams.

101 An extract from *Fortune Magazine*, Nov. 1974, submitted by Mr L. Williams.

	Brief	Organization	Transcript pages	Exhibit	
Toronto (continued)					
Feb. 17/75	106	Mr M. Gervalis, Local 6166, United Steelworkers of America, Thompson, Manitoba	3433–50	102	(1) Booklet entitled *Miner Trade*, Practical on-the-job training – Apprentice rotation. (2) Course outline for miner training. (3) *Regulation under the Apprenticeship and Tradesmen's Qualification Act Respecting the Miner Trade*, submitted by Mr M. Gervalis of Local 6166, United Steelworkers of America, Thompson, Manitoba.
Feb. 17/75	107	Prof. F.H. Knelman, Concordia University, Consultant to United Steelworkers of America	3485–3548		
Feb. 17/75	108	Mr K. Valentine, United Steelworkers of America, District 6.	3548–56		
Feb. 18/75	109	Mr R. Moreau, President, Local 6200, United Steelworkers of America	3558–3613	103	Diagram showing plant layout and correspondence submitted by Mr R. Moreau, President, Local 6200, United Steelworkers of America.

				104 No. 505 Safety Mask and piece of cloth, submitted by Mr R. Moreau.
Feb. 18/75	110	Mr C. Lambert (for M. Keck) Local 1177, United Steelworkers of America	3613–43	105 Letter from Department of Health to Dr V.L. Tidey, Jan. 18/72, submitted by Mr C. Lambert.
Feb. 18/75	111	Mr Stephen Lewis, Leader of the New Democratic Party	3644–78	106 Appendices A, B, C, D, E, and F to brief submitted by Mr Stephen Lewis, Leader of the New Democratic Party and member of the Ontario Legislature for the riding of Scarborough West.
Feb. 18/75	112	Mr John Lennie, Chairman of the Accident Prevention Workmen's Compensation Safety and Health Committee, Local 1005, United Steelworkers of America	3678–3713	107 Employment and accidents in mines from 1947 to 1971, submitted by Mr John Lennie, Chairman of the Accident Prevention, Workmen's Compensation Safety and Health Committee of Local 1005, United Steelworkers.
				108 Letter dated July 18/73, from Mr Leo Bernier and letter from Mr McWhinney dated July 24/73, submitted by Mr John Lennie.
				109 Extract entitled 'Occupational health in Ontario,' p. 5, dated

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				Dec. 1970, submitted by Mr John Lennie.
				110 Letter from Department of Health dated 1963 submitted by Mr John Lennie.
				111 Extract from *Globe and Mail*, dated Feb. 6/75, relating to asbestos, submitted by Mr John Lennie.
				112 Extract from *Safety Canada* submitted by Mr John Lennie.
				113 Volume of printed material supporting presentation by Mr Lennie.
				114 Jan. 1975 issue of publication entitled *Occupational Hazards*, p. 2, and Dec. 1974 issue containing advertisement following p. 7, submitted by Mr John Lennie.
				115 Pamphlet published by Dr John Campbell entitled *You can't pay a man to risk his life*, submitted by Mr John Lennie.
Feb. 18/75	113	Mr B.L. Rochester, Individual	3714–63	
Feb. 18/75	114	Mr C. Head, Individual	3763–8	

Ottawa

April 7/75	115	Machinery and Equipment Manufacturers' Association of Canada	3771–3813	116 CAGI-Pneurop Test Code for the measurement of sound from pneumatic equipment, submitted by Mr Jack Alexander, Vice-President and Chairman of MEMAC.
April 7/75	116	Mr H. Maxwell, Treasurer Local 5414, United Steelworkers of America	3814–34	
April 7/75	117	Mr H. Lowrey, Financial Secretary, Local 5414, United Steelworkers of America	3834–52	
April 7/75	118	Mr G. Rigby, President, Local 5383, United Steelworkers of America	3852–74	
April 7/75	119	Mrs J. Shulist, Individual	3877–81	117 Letter from Dr G.D. Hooper to Mr J.F. Cauley, Vice-Chairman of Workmen's Compensation Board, submitted by Mrs J. Shulist.
April 8/75	120	Mrs J. Shushack, Individual	3881–3	
April 8/75	121	Mrs Veronica Kelly, Individual	3884–7	
April 8/75	122	Mr K. Rubin, Individual	3887–94	

	Brief	Organization	Transcript pages	Exhibit
Ottawa (continued)				
April 8/75	123	Mr P. Curtis, Technical Advisor, Confederation of National Trade Unions (CNTU)	3897–3979	118 Arbitration Notice between Noranda Mines Ltd (Geco Division) and the Canadian Union of Basic Metal Workers, submitted by Mr. P. Curtis, technical adviser with the Federation of National Trade Unions.
April 8/75	124	Mr C. Clarke, President, Local 4632, United Steel-workers of America	3979–4081	119 Magazine article entitled 'Dominion Magnesium – war time baby – peace time asset,' Aug. 17/71, sub-mitted by Mr C. Clarke, President, Local 4632, United Steelworkers.
				120 Photograph album containing photographs submitted by Mr C. Clarke.
				121 *Agreement between Chromasco Corp. Ltd and the United Steelworkers, Local 4632, 1973 to 1975*, submitted by Mr C. Clarke.
April 8/75	125	Mr A. Gray, Chairman Safety Committee, Local 4854, United Steelworkers of America	4081–4107	

Toronto					
May 26/75	126	Ontario Federation of Labour	4110–43	122	Appendix A with two tables attached to the brief of the Ontario Federation of Labour, submitted by Mr H. Weisbach, Director of the Health and Safety Branch.
May 26/75	127	Energy Mines and Resources of Canada, (Canada Centre for Mineral and Energy Technology)	4143–4213	123	Bibliography of Energy Mines and Resources, prepared by Canada Centre for Mineral and Energy Technology and submitted by Dr W.M. Gray, Senior Scientist of the Mining Research Laboratories (Division of Canada Centre).
May 26/75	128	Ontario Ministry of Labour: The Women's Bureau, Women's Program Division	4213–23		
May 27/75	129	Rio Algom Mines Ltd.	4225–98		
May 28/75	130	Mr G. Markel, National Office, United Steelworkers of America	4301–86	124	Added portions to submission by United Steelworkers (Page 11 (a) of brief, an extract from articles in the *Washington Post* and Workmen's Compensation Board Claim Form #7) submitted by Mr G. Markle of United Steelworkers.
May 28/75	131	Dr C. Stewart, Chest Disease Specialist, Workmen's Compensation Board	4386–97		

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				
May 29/75	132	Ontario Mining Association	4398–4606	125 Extract from Position Paper No. 4 *Fortune* – April 1975, and reprint from the *1974 National Safety Congress Transactions – Mining Safety Section*, submitted by Mr N.A. Wadge, Executive Director, Ontario Mining Association.
				126 Publication *Steel Labour*, April 1974, submitted by Mr N.A. Wadge.
				127 Copy of a brief from the Commission of Inquiry dated Oct. 1974, submitted by Mr N.A. Wadge.
				128 Report of the Advisory Committee on Industrial Training dated 1968 entitled *Industrial Training*, submitted by Mr N.A. Wadge.
				129 Document on Ontario Mining Association letterhead dated Nov. 2/71, addressed to the Task Force on Industrial Training, submitted by Mr N.A. Wadge.
				130 Memorandum – Dust Control in

				Uranium Mines, dated May 25/55, submitted by Mr N.A. Wadge.
				131 Minutes of meeting of the Labour Safety Council of Ontario held March 11/74, submitted by Mr N.A. Wadge.
May 29/75	133	Mr K. Valentine, National Office, United Steelworkers of America	4606–12	
May 30/75	134	Dr Thomas Hollocher, Brandeis University, United Steelworkers of America Consultant	4615–52	132 Chapter 5 – 'The nuclear fuel cycle,' submitted by Dr Thomas Hollocher of Brandeis University and a Consultant of the United Steelworkers.
May 30/75	135	Dr Robert Morgan, Professor at the University of Toronto, Department of Preventive Medicine, appearing on behalf of United Steelworkers of America	4652–72	
June 2/75	136	Workmen's Compensation Board, Hon. Michael Starr, Chairman, Dr Charles Stewart, Chest Disease Specialist, Mr William Kerr, Executive Director, Board's Claims Services Division	4675 4849	

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				
June 3/75	137	District 6, United Steelworkers of America, Mr L. Williams, Director, Mr K. Valentine, Educational Department, Mr B. Munro, Legislative Director, Mr P. Warrian, Legislative Department, Mr R. Stephenson, Public Relations	4851–4979	133 Brief on Bill 2 on Revisions to the Mining Act dated March 1970, submitted by Mr Bert Munro, Legislative Director of United Steelworkers. 134 Brief No. 2, United Steelworkers (Elliot Lake) 1959, submitted by Mr B. Munro.
June 3/75	138	Mr Nitchie, President, Local 598, Mine, Mill and Smelter Workers Union	4980–5016	
	138A	Mr D. Cochrane, Co-Chairman, Health and Safety Committee, Local 6500, United Steelworkers of America	5017–65	
	138B	Mr K. Rothney, Local 6500, United Steelworkers of America	5065–5110	
June 4/75	139	Ministry of Natural Resources, Mines Engineering Branch, Hon. Leo Bernier, Minister, Dr J.K. Reynolds, Deputy Minister, Mr G.	5113–5391	135 Resource Document 1 – D.P. Douglas Resource Document 2 – W.E. Bawden Resource Document 3

Jewett, Executive Director, Division of Mines, Mr P. McCrodan, Director, Mines Engineering Branch, Mr E. Isaac, Regional Mining Engineer, Sudbury, Mr Cam Barrett, Chief Electrical-Mechanical Engineer, Mines Engineering Branch

– R.L. Smith
Resource Document 4
– H.F. Davis
Resource Document 5
– W.A. Hoffman
Resource Document 6
– W.V. McKnight
Resource Document 7
– E.W. McIsaac
Resource Document 8
– G.G. McPhail
Resource Document 9
– R.F. Lockhart
submitted by Mr Peter McCrodan, Director, Mines Engineering Branch, Ministry of Natural Resources.

136 Organization of the Ministry of Natural Resources according to principles established in the General Guide to Organization and Management Systems released in 1973, submitted by Dr J.K. Reynolds, Deputy Minister, Ministry of Natural Resources.

137 4 letters presented by Mr P. McCrodan, Director, Mines Engineering Branch, Ministry of Natural Resources.

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				
June 5/75	140	Atomic Energy Control Board	5393–5478	
June 5/75	141	Canadian Diamond Drilling Association	5478–93	138 Table; Fatal Accident Reports re: Mr Gaston Tremblay and Mr François Côté, submitted by Mr C. Steine, Managing Director of Canadian Diamond Drilling Association.
June 6/75	142	Ministry of Health, Dr S.W. Martin, Deputy Minister; Mr W.A. Backley, Assistant Deputy Minister; Dr V. Tidey, Acting Director, Occupational Health Protection Branch	5496–5654	139 Dr S.W. Martin, Deputy Minister, Ministry of Health, submitted the following nineteen items: 1/J.F. Paterson, *Silicosis in Hard rock Mines in Ontario*, Bulletin 173 Ontario Ministry of Natural Resources, Toronto: July 1973. 2/E. Mastromatteo, 'Noxious gases in mining operations,' *Canadian Mining Journal*, Oct. 1967. 3/G.S. Rajhans, 'Fibrous dust – its measurement and control,' *Canadian Mining and Metallurgical Bulletin*, Aug. 1970. 4/J.E. Cowle, 'Health hazards of dust inhalation (pneumoconiosis),' *Canadian Mining Journal*, Oct. 1970.

5/G.S. Rajhans, ‘Considerations in duct design,’ *Canadian Mining Journal*, Oct. 1970.

6/G.S. Rajhans, ‘Talc dust and its toxicity,’ *Canadian Mining and Metallurgical Bulletin*, April 1974.

7/G.S. Rajhans, ‘Sampling of air-borne dust with membrane filters,’ *Canadian Mining Journal*, Oct. 1968.

8/*Survey of Dust, Radiation & Diesel Exhaust in Uranium Mines and Mills at Elliot Lake, Ontario*, Ontario Ministry of Health, Occupational Health Protection Branch, Toronto, Ontario, Nov. 1974.

9/*Survey of Certain Conditions of the Respiratory Organs Among Persons Employed Underground and in Surface Crushers and Mills of Two Operating Uranium Mines at Elliot Lake – February 17 – March 30, 1974*, Ontario Ministry of Health, April 1975.

10/J. Muller and W.C. Wheeler, ‘Causes of death in Ontario uranium mines,’ paper presented at the International Symposium on Radiation Protection in Mining and Milling of Uranium and Thorium; Bordeaux, France, Sept. 1974.

	Brief	Organization	Transcript pages	Exhibit
Toronto (continued)				11/*Occupational Noise, A project team report*, Ontario Ministry of Health, Dec. 1974. 12/J. McEwan, *Report on Sputum Cytology Programs (1973 and 1974)*, Ministry of Health, Feb. 1975. 13/J. Muller, *Criteria for Radon Daughter Concentrations in Uranium Mines*, Ontario Ministry of Health, May 1975. 14/*Threshold Limit Values for Chemical Substances in Workroom Air – Adopted by ACGIH for 1974*, Cincinnati, Ohio. 15/E. Mastromatteo, 'Threshold limit values,' paper prepared for the Environmental Health Branch, Ontario, Department of Health, Jan. 1968. 16/*Occupational Exposure to Crystalline Silica*, US Department of Health, Education and Welfare, Public Health Service, Centre for Disease Control, National Institute

for Occupational Safety and Health, 1974.

17/*Documentation of the Threshold Limit Values for Substances in Workroom Air*, American Conference of Governmental Industrial Hygienists, Third Edition, 1971.

18/*Recommended Standards and Guidelines for Occupational Audiometric Testing Programs*. A brochure published by the Ministry of Health, March 1975.

19/'An unusual pneumoconiosis in the Ontario mining industry,' Dr J.E. Cowle and Dr E. Mastromatteo, Professor A.G. Ritchie, *Transactions of the 34th Annual Meeting of the American Conference of Government and Industrial Hygienists*, San Francisco, California, May 14/72.

140 Minutes of the Labour Safety Council of Ontario subcommittee on construction in mining dated May 11/74, submitted by Mr K.A. Valentine, United Steelworkers of America.

BRIEFS TRANSMITTED TO THE COMMISSION BUT NOT PRESENTED AT PUBLIC HEARINGS

May 29/75	143	Conservation Council of Ontario Mr C.E. Goodwin, Executive Director
Dec. 16/75	144	United Autoworkers of America, Local 195, Mr S. Gindin, Research Director; Mr G. Becigneul, Chairman Health and Safety Committee
Feb. 24/76	145	Canadian Institute of Public Health Inspectors, Ontario Branch, Mr R. De Burger, Chairman, Education Committee

APPENDIX C: RADIOGENIC LUNG CANCER IN ONTARIO URANIUM MINERS 1955–74

The findings presented in this appendix are based on data about eighty-one deaths of miners or former miners from lung cancer during the period 1955–74 (see Table C.4), together with corresponding data on eighty-one other miners who were still alive at the end of that period. That is, these findings are derived from comparisons *internal* to the population listed on the Uranium Nominal Roll. For proper interpretation of these findings it is necessary to keep in mind the main mortality study, as summarized in chapter 3, in which the miners' experience of lung cancer was compared with an *external* standard, namely, that set by the contemporary mortality rates of Ontario male residents. It was there inferred that the eighty-one lung cancer deaths comprise a mixture, in approximately equal proportions, of cases that would have occurred even if the miners had not been exposed to any unusual risks and cases attributable to the special circumstances of uranium mining.[1]

Work histories have been compiled by the Workmen's Compensation Board for all current and former Ontario uranium miners, but not in machine-readable form, so that to have analysed this material in its entirety would have involved unjustifiable cost and delay. A comparison series for the lung cancer cases was therefore constituted on a sample basis (with a saving of approximately two and one-half man-years of clerical work) as follows. From among members of the Nominal Roll whose certificate numbers ended in the randomly chosen digits 34, of whom there were 158, there were first eliminated eleven men known to have died within the study period. Of the 147 survivors, 80 who had been born in or before February 1933 were of an age to have been in the work force when hiring began for the Ontario uranium mines in 1954 – as were 80 of the 81 fatal lung cancers so far ascertained – and these were all included in the comparison series. To

balance the one cancer case born in 1936, one more comparison subject was selected at random from among the five available survivors in the 1 per cent sample who had been born in that year.

The use of randomly selected *surviving* subjects for the comparison series was convenient and appropriate, but unless a special correction was made it could have introduced a bias in the comparison of exposure histories. This would arise because the survivors could continue to work and to accumulate further exposure right up to the end of 1974, by which time all members of the case series were dead. To counteract this bias each member of the comparison series was assigned a notional 'year of death,' equal to the actual year of death of a case with which it had been paired in a random fashion. (For this matching the cases were sequenced in order of entering the industry, survivors in the order – approximately alphabetical – in which they appear in the Nominal Roll.) Exposures incurred later than this notional year of death were then deleted from the data.

An initial comparison between the lung cancer cases and the survivors in terms of the number of months worked in Ontario uranium mines showed that the cases, with an average of 43.2 months, had significantly longer exposure than the survivors (average of 25.6 months), by a margin of 69 per cent. When these months are weighted by the corresponding exposure levels (based on mine averages for years up to 1968 and on personal records thereafter) to obtain average numbers of Working Level Months, the margin of difference widens to 127 per cent (cases 74.5 WLM, survivors 32.8 WLM). Thus the records of exposure level, however imperfect they may be, do yield an index that discriminates more effectively between cases and survivors than the index based on duration of exposure alone. This strengthens the presumption that ionizing radiation, rather than some other, as yet unidentified, factor associated with uranium mining is responsible for the excessive frequency of lung cancer in uranium miners. These statistics also illustrate the distinctive character of the experience in Ontario, where the typical exposures have been in the under–100 WLM range, concerning which there is little to be learned from the US data except by hazardous extrapolation (Lundin et al., 1971).

Though the exposures reported in the present study are small compared with those reported from Colorado, they are just as likely to overstate the quantity of radiation actually needed to produce cancer, and this for the same essentially statistical reason, which needs to be clarified before the exposition is taken further. The process of carcinogenesis in man is believed to require a lapse of time between a causal exposure and its overt effect which is both long, being measured in years or even decades, and

highly variable between individuals. Empirical studies further suggest that the statistical distribution of such time intervals may be of lognormal form (Armenian and Lilienfeld, 1974), that is, with the majority of cases developing after a period of time exceeding the modal interval. This lapse of time provides an opportunity for subjects who have already been affected by prior exposure to accumulate further exposures, which contribute nothing to the outcome already determined and yet add to the apparent dose. If, for each individual, the amounts of exposure in successive time intervals were independent, these adventitious extra doses would shift the dose-response curve to the right (possibly suggesting the presence of a 'quasi-threshold': Stewart, 1975) but would not otherwise modify its slope to any important extent. In the real world, however, there will usually be some correlation of exposure levels between successive time intervals. Negative correlation would tend to obliterate the exposure difference between affected and unaffected subjects. Positive correlation between time intervals[2] would tend to inflate this difference, thus overstating the amount of exposure required to produce an effect and understating the increment of risk per unit exposure. This point can easily elude any investigator who is accustomed to think in terms of research by means of tidily planned experiments – in which such complications can be prevented from arising – rather than in terms of an observational discipline such as epidemiology.

If the form and parameter values of the latent interval distribution were already known, one could compute the 'relevant' dose for each subject as an appropriately weighted sum of the doses received in each time-interval prior to death or onset. Unfortunately this is not the situation with radiogenic lung cancer: no certainly appropriate set of weights is yet available, and various plausible sets suggest wholly different values of risk per unit dose. It is hoped that further analyses of the Ontario data will help to define the latent interval distribution for radiogenic lung cancer. In this interim report the convention has been adopted of giving all intervals equal weight, except for the terminal interval, which is given zero weight.[3] This is the basis on which Table C.1 and Figure C.1 have been constructed, for the sole purpose of testing whether there is any detectable dependence of lung cancer risk on dose within the range of doses experienced by Ontario uranium miners. This analysis is most emphatically not offered as the basis for any estimate of risk per unit dose. In Table C.1 the lung cancer cases and surviving subjects are classified into three major ranges of WLM. A test has been made of the null hypothesis that the underlying distribution over these ranges was the same for cancer deaths and for survivors. This hypothesis was easily discredited ($\chi^2_{(2)} = 11.76$; $P < 0.005$), the data favouring a

TABLE C.1

Dependence of lung cancer risk on total WLM

Range of total WLM	Numbers of [cancer deaths / comparison survivors] in this range of WLM: Observed		Expected: A If risk not related to WLM	Expected: B If risk increases linearly with WLM
0	[1 / 4]	[30 / 48]	[39.00 / 39.00]	[26.20 / 51.80]
1–29	[29 / 44]			
30–59	[17 / 20]	[26 / 24]	[25.00 / 25.00]	[27.75 / 22.25]
60–89	[9 / 4]			
90–119	[5 / 4]	[25 / 9]	[17.00 / 17.00]	[27.05 / 6.95]
120+	[20 / 5]			
Total	[81 / 81]		[81.00 / 81.00]	[81.00 / 81.00]
Goodness of fit between observed and expected			$\chi^2_{(2)} = 11.763$, $P < 0.005$	$\chi^2_{(1)} = 1.838$, $P > 0.17$

NOTE: See Figure C.1.

displacement of cases towards higher WLM or, to put it more familiarly, an increase in lung cancer risk with increasing dose.

The next simplest hypothesis is that of a linear dependence of risk [indexed by the ratio cases/(100 × survivors)], as plotted in Figure C.1 for six ranges of total WLM. The area of each spot in this diagram has been made proportional to the quantity $(CS)/(C + S)$, where C and S are the numbers of cancer cases and surviving subjects within the dose range. These quantities were also used as weights in computing the fitted straight line, from which, in turn, were computed the expected frequencies shown in the right-hand column of Table C.1. Because this fitting procedure absorbs one degree of freedom, there is only one degree of freedom left for testing the goodness of fit between the observed frequencies (30, 48; 26, 48;

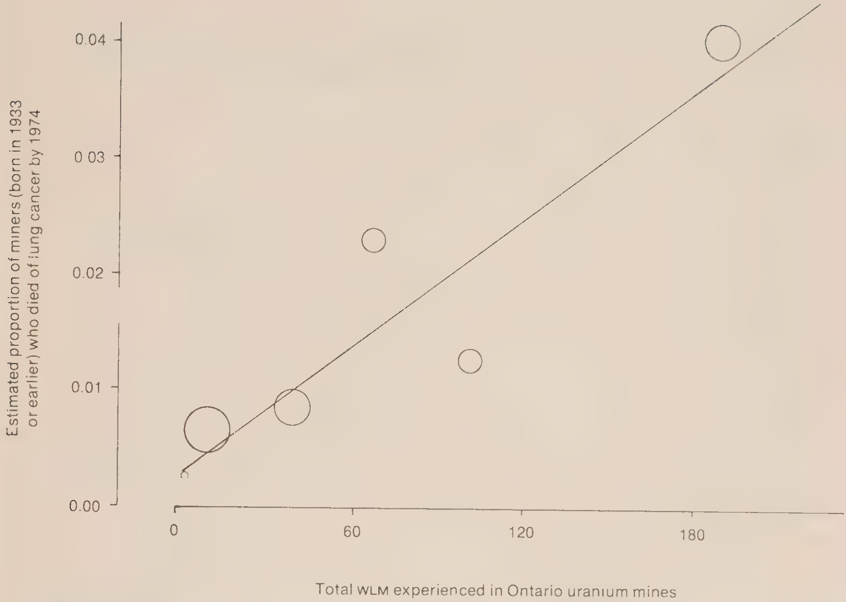


FIGURE C.1 Relationship between total WLM experienced in Ontario and risk of lung cancer.

25, 9) and the second set of expected frequencies (26.20, 51.80; etc.). The comparatively small discrepancies are now within the limits of chance fluctuation ($\chi^2_{(1)} = 1.83$; $P > 0.17$). Hence there is no statistical justification for fitting any more complex model (threshold, multiple hit, etc.) to these data. The possibility of a 'safe' threshold dose cannot be excluded by these, or by any other finite amount of data. However, further analyses, to be reported in full elsewhere, have shown that, to be at all plausible in relation to the Ontario experience, a postulated threshold would have to be lower than 10 WLM.

Given that there is dose-dependent variation in cancer risk within the range of doses experienced by Ontario uranium miners, together with some knowledge of historical and geographical variations in working levels within the province (see Table 18 in text), two testable predictions can be made:

1 A history of employment at the Bancroft camp will prove to be as-

TABLE C.2

Estimates of relative risk associated with area and calendar period of entry into uranium mining in Ontario

Characteristic of cases	Cancer cases (N)	Surviving subjects (N)	Relative risk estimate	
Ever worked in Bancroft area	28	16	Risk of dying of cancer by 1974 for persons ever working in Bancroft area relative to those who never worker there	$= \frac{28}{16} \Big/ \frac{53}{65} = 2.1^{a}$
Never worked in Bancroft area	53	65		
Entered exposure in or before 1957	53	35	Risk of dying of cancer by 1974 for persons entering exposure before 1958, relative to those who entered thereafter	$= \frac{53}{35} \Big/ \frac{28}{46} = 2.5^{b}$
Entered exposure in or after 1958	28	46		

a Significant at $P < 0.05$
b Significant at $P < 0.01$

sociated with a high relative risk of lung cancer (MacMahon and Pugh, 1970). This prediction is verified, at a satisfactory level of statistical significance, by the figures shown in the upper half of Table C.2, where it appears that men with any period of employment at Bancroft have experienced a lung cancer risk about twice as great as that for men who have worked only at Elliot Lake.[4]

2 Early entry into the industry will prove to have been associated with a high relative risk of lung cancer. This prediction is verified, at a satisfactory level of statistical significance, by the figures shown in the lower half of Table C.2, where it appears that men whose exposure began in the first few years of the industry have experienced a lung cancer risk more than double that of cohorts entering in 1958 or later years.

The principal shortcoming of the Ontario study material on lung cancer in uranium miners is that at present it contains no data on individual smoking habits that can be linked to the radiation exposure histories. This is unfortunate because cigarette smoking is quite possibly a more important determinant of lung cancer, even in this irradiated population, than the radiation itself, and it is important to gain some appreciation of the way in which these two factors relate to one another – whether, for example, their effects on cancer risk are simply additive or multiplicative. However, there

TABLE C.3

Estimate of relative risk associated with WLM of 30 or more, by age at entry into uranium mining in Ontario

Age at entry	Total WLM	Number of cancer cases	Number of survivor subjects	Relative risk estimate
Up to 35	Up to 29	7	28	$\frac{15}{25} \Big/ \frac{7}{28} = 2.4$
	30 and over	15	25	
36 and over	Up to 29	23	20	$\frac{36}{8} \Big/ \frac{23}{20} = 3.9$
	30 and over	36	8	

is no shortage of information on age, which in turn is an even more important determinant of risk than smoking, in as much as the death rate from lung cancer increases approximately with the seventh power of age (data for Ontario male residents aged 25–65, period 1960–9). The interaction between the factors of age and exposure to the uranium mining environment was analysed in the general mortality study, where miners' lung cancer deaths in excess of the Ontario male standard were found to have an age-distribution incompatible with the hypothesis of simple additivity, and in good agreement with a multiplicative effect. That is, age-specific mortality rates were found to be increased by a constant *factor*, rather than by an equal absolute amount. This question, which is vital for prediction, and hence for policy-making, can also be studied on the basis of comparisons internal to the mining population, and Table C.3 has been drawn up to illustrate the method. If exposure to 30 or more WLM entailed the same additional risk of lung cancer for miners of any age, then the relative risk (MacMahon and Pugh, 1970) would be much higher at young ages (when spontaneous cancer rates are much lower). So far from this being the case, Table C.3 indicates a relative risk for men first exposed after age thirty-six fully as high as, if not higher than, for those exposed before age thirty-five.[5]

It is therefore reasonable to infer that a given amount of exposure can be more harmful to a subject whose expectation of cancer is already high than to one whose expectation is lower. Strictly speaking this has only been shown in relation to age, but it would be prudent to think in terms of more-than-additive effects when radiation is conjoined with other risk factors, possibly even including previous irradiation. In this way it would also be possible, without postulating any true threshold, to accommodate

TABLE C.4

Characteristics of the lung cancer cases

Case number	Year of birth	Year of entry into uranium mines	Age at entry	Year of death	Age at death	Elapsed time from entry to death in years	Years of exposure to dust and radiation[a]	Cumulative exposure in WLM[b]	Average WLM per annum during exposure	Worked at Bancroft mine(s)	Years of exposure in uranium mines outside Ontario
1	1915	1954	39	1963	48	9	6.0	375	62.5	x	
2	1913	1955	42	1966	53	11	9.3	368	39.6	x	
3	1912	1957	45	1974	62	17	13.3	258	19.4		
4	1918	1955	37	1970	52	15	8.4	236	28.1		
5	1928	1958	30	1971	43	13	10.6	225	21.2		
6	1914	1956	42	1974	60	18	8.3	216	26.0		0.6
7	1919	1957	38	1974	55	17	11.5	209	18.2		
8	1926	1956	30	1961	35	5	3.9	193	49.5	x	
9	1915	1955	40	1974	59	19	17.7	186	10.5		
10	1912	1957	45	1969	57	12	6.7	180	26.9	x	
11	1931	1957	26	1972	41	15	6.8	179	26.3	x	
12	1913	1957	44	1970	57	13	7.9	175	22.2		
13	1899	1955	56	1963	64	8	2.7	172	63.7	x	5.0
14	1921	1957	36	1974	53	17	5.5	160	29.1	x	
15	1927	1956	29	1967	40	11	5.4	143	26.5		
16	1913	1955	42	1973	60	18	2.2	139	63.2	x	
17	1927	1957	30	1969	42	12	3.2	129	40.3	x	
18	1916	1954	38	1974	58	20	6.3	124	19.7		
19	1922	1960	38	1970	48	10	3.6	122	33.9		
20	1930	1957	27	1972	42	15	5.2	121	23.3		
21	1906	1955	49	1961	55	6	4.7	99	21.1		
22	1916	1957	41	1970	54	13	13.0	96	7.4		5.1
23	1901	1957	56	1970	69	13	2.0	94	47.0	x	
24	1919	1957	38	1974	55	17	15.4	92	6.0		
25	1909	1955	46	1971	62	16	4.3	90	20.9		
26	1915	1955	40	1974	59	19	4.8	79	16.5		

27	1924	1957	33	1962	38	5	3.3*	73	22.1		
28	1910	1960	50	1967	57	7	1.8	71	39.4		
29	1914	1956	42	1972	58	16	5.3	70	13.2	x	
30	1916	1957	41	1974	58	17	7.3	64	8.8		0.4
31	1907	1955	48	1959	52	4	3.2	64	20.0		
32	1921	1956	35	1966	45	10	5.0	63	12.6		
33	1897	1957	60	1968	71	11	2.0	63	31.5	x	
34	1919	1958	39	1974	55	16	6.1	62	10.2		
35	1932	1958	26	1967	35	9	7.1	56	7.9		
36	1918	1957	39	1962	44	5	4.1	53	12.9		
37	1913	1958	45	1973	60	15	6.0	54	9.0		
38	1910	1955	45	1966	56	11	7.0*	49	7.0		
39	1920	1957	37	1968	48	11	2.9	48	16.6	x	
40	1919	1957	38	1973	54	16	2.3	46	20.0		
41	1914	1956	42	1972	58	16	5.6*	43	7.7	x	
42	1913	1957	44	1972	59	15	3.0	39	13.0	x	
43	1924	1957	33	1968	44	11	3.0	37	12.3	x	
44	1910	1956	46	1974	64	18	1.6	37	23.1	x	
45	1932	1958	26	1974	42	16	4.1	37	9.0	x	
46	1929	1957	28	1971	42	14	2.9	37	12.8		
47	1905	1958	53	1961	56	3	1.7	33	19.4	x	
48	1904	1956	52	1970	66	14	1.6	33	20.6		
49	1923	1955	32	1971	48	16	2.6*	33	12.7		
50	1922	1958	36	1971	49	13	0.8	32	40.0	x	
51	1922	1957	35	1973	51	16	2.1	31	14.8	x	
52	1901	1958	57	1969	68	11	3.2	30	9.4		
53	1914	1957	43	1966	52	9	1.8	30	16.7		
54	1927	1957	30	1974	47	17	1.6	28	17.5		
55	1910	1958	48	1963	53	5	2.7	23	8.5		
56	1912	1954	42	1973	61	19	0.8	23	28.8		
57	1918	1959	41	1968	50	9	1.8	22	12.2		
58	1936	1958	22	1974	38	16	1.6	21	13.1	x	
59	1919	1957	38	1974	55	17	0.4*	20	50.0	x	
60	1912	1956	44	1972	60	16	1.3	18	13.8		
61	1912	1955	43	1960	48	5	3.5*	15	4.3		
62	1925	1957	32	1971	46	14	1.1	12	10.9		
63	1928	1958	30	1970	42	12	1.2	9	7.5		
64	1913	1959	46	1966	53	7	1.0	9	9.0		1.5

TABLE C.4 (concluded)

Case number	Year of birth	Year of entry into uranium mines	Age at entry	Year of death	Age at death	Elapsed time from entry to death in years	Years of exposure to dust and radiation[a]	Cumulative exposure in WLM[b]	Average WLM per annum during exposure	Worked at Bancroft mine(s)	Years of exposure in uranium mines outside Ontario
65	1916	1955	39	1968	52	13	0.5	9	18.0		
66	1904	1959	55	1963	59	4	1.0*	9	9.0	x	
67	1926	1958	32	1971	45	13	0.8	8	10.0		
68	1922	1958	36	1972	50	14	0.5	7	14.0		
69	1910	1959	49	1972	62	13	0.4	7	17.5		
70	1923	1958	35	1964	41	6	0.4	7	17.5		
71	1926	1959	33	1973	47	14	0.2	6	35.3	x	
72	1902	1959	57	1973	71	14	0.2	6	35.3	x	
73	1909	1956	47	1974	65	18	1.0*	5	5.0		
74	1919	1958	39	1974	55	16	0.5	4	8.0		
75	1908	1958	50	1971	63	13	0.1	4	50.0	x	
76	1920	1957	37	1969	49	12	0.3	4	16.0		
77	1914	1957	43	1973	59	16	0.2	3	17.6	x	
78	1912	1958	46	1969	57	11	0.6	3	5.2		
79	1921	1958	37	1972	51	14	0.2	2	11.8		
80	1915	1959	44	1962	47	3	0.1	1	12.5		
81	1921	1963	42	1971	50	8	2.3	0	0		
82	1921	1957	36	1967	46	10	7.8	220	28.2		
83	1910	1957	47	1973	63	16	2.6	18	6.9		
84	1912	1956	44	1971	59	15	1.0	6	6.0		

NOTE: Nos 82, 83, and 84 of list have been excluded from other statistical analyses. They are known to have had lung cancer, but their deaths were certified to other causes.

a Excludes periods of continuous surface work. Asterisk indicates some admixture of surface with underground work.

b WLM were estimated to two decimal places, here rounded to nearest whole number.

SOURCE: Commission study of mortality experience of uranium mines

the idea of a response more than proportional to cumulative dose. Finally, it must be stressed that the evidence reviewed here all relates to effects expressed within twenty years of exposure. In the long run, when effects are summed over the remaining lifespan of those exposed, it could well be that exposure of a younger subject is more harmful than physically equivalent exposure of an older subject; indeed, this is quite likely to be true if the latent interval distribution does have a lognormal form.

DAVID HEWITT, *Associate Professor, Department of Preventive Medicine and Biostatistics, University of Toronto*

1 A conservative estimate of the component attributable to occupational factors is 44 per cent (=(81 – 45)/81); a more realistic estimate, incorporating an allowance for under-ascertainment of miners' deaths in the present study, is 52 per cent (=(93 – 45)/93). Three additional deaths of miners, known to have had lung cancer but certified as having died of other causes, have been omitted from both the external and internal comparisons.
2 For 159 miners surviving through 1961, the correlation between WLMs received in 1960 and 1961 was +0.742.
3 The intervals used in the analysis are necessarily calendar years. For members of the survivor series the terminal year is a full twelve-month period; for cases, it is on average only six months long and falls mainly within the period between diagnosis of the fatal illness and death.
4 With or without some out-of-province exposure in uranium mines
5 It may also be observed in Table C.3 that, within the comparison series taken to be representative of the uranium mining population generally, a higher proportion of the younger men accumulated a dose in excess of 30 WLM (25/53 compared with 8/28). It seems that any bias introduced by omission of age-matching (except at the cut-point of birth in 1933) may have been a conservative one. In other words, it is reasonable to suppose that a comparison using more precise age-matching would have yielded at least as strong a contrast between cases and survivors as that shown in Table C.1 and Figure C.1.

REFERENCES

Armenian, H.K. and A.M. Lilienfeld (1974) *American Journal of Epidemiology*, 99, 92

Lundin, F.E. jr, J.K. Wagoner, and V.G. Archer (1971) *Radon Daughter Exposure and Respiratory Cancer: Quantitative and Temporal Aspects*, National Institute for Occupational Safety and Health, National Institute of Environmental Health Sciences, Joint Monograph No. 1, US Dept of Health, Education and Welfare

MacMahon, B. and T.F. Pugh (1970) *Epidemiology – Principles and Methods*, Boston

Stewart, C.G. (1975) 'Dose response relations: the incidence of carcinomas of the lung in uranium miners,' lecture given to the Japan Nuclear Safety Research Association

APPENDIX D: STATISTICAL TABLES

TABLE D.1

Average dust levels for underground operations by metal group 1958–75

Year/ Month	Uranium	Gold (all)	Other	Nickel	Copper	Iron	Silver	Miscellaneous industrial metals
1958								
3								
9	473							
1959								
3	407							
9	401							
1960								
6	402	402	676	677				
11	359	393	529	550				
1961								
6	335	374	515	552				
12	335	397	504	505				
1962	310	379	443	459				
9	367	329	439	402				
1963								
3	314	303	–	370	342	341	308	
9	289	263	–	369	344	442	300	450
1964								
4	288	307	–	382	340	391	323	–
9	286	256	–	396	290	326	298	–
1965								
3	362	270	–	414	371	401	269	–
9	284	245	–	417	306	460	396	–

1966								
4	260	243	–	410	352	335	432	375
9	249	245	–	390	372	313	374	410
1967								
3	285	218	–	380	363	413	446	391
9	299	199	–	375	331	303	400	258
1968								
3	287	191	–	361	353	298	374	348
9	303	213	–	336	282	293	354	343
1969								
4	321	211	–	327	338	283	292	492
9	300	232	–	352	279	285	332	334
1970								
4	348	231	–	380	334	226	340	362
9	262	207	–	344	264	302	294	658
1971								
3	261	275	–	354	323	297	315	384
10	257	241	–	346	329	332	196	410
1972								
3	217	202	–	355	299	312	202	–
9	259	230	–	335	331	366	306	–
1973								
3	249	216	–	305	262	314	201	346
9	225	204	–	234	233	275	142	–
1974								
3	253	267	–	286	284	302	281	365
9	224	241	–	266	254	277	270	–
1975								
3	221	248	–	309	301	223	196	–

NOTE: Levels in particles per cubic centimetre as measured by a konimeter. Data for years 1958–64 are compiled from original records of mines and are an average of the operation averages divided by the number of mines in operation. 'Other' includes uranium mines and Sudbury mines. Levels for nickel mines 1960–2 are recorded as Sudbury in surveys.

SOURCE: Original records of the mines as submitted to and compiled by the Mines Accident Prevention Association of Ontario and the Ministry of Natural Resources.

TABLE D.2

Average dust levels for selected underground locations and operations within uranium mines 1958–75

Year/ Month	Headings drilling	Headings loading	Raises drilling	Stopes drilling	Stopes loading	Stopes scraping	Under-ground crusher	Dumping	Main drives and cross cuts	Primary[a] crushing	Cubic feet[b] per minute per ton hoisted per day (thousands)
1958											
3	468	532	650	482	631	–	1000	581	–	329	–
6	513	559	632	492	500	–	–	-	310	500	–
9	543	642	638	466	523	–	395	476	326	555	–
1959											
3	392	474	568	445	485	–	369	442	301	–	–
6	405	492	547	420	433	–	370	430	269	438	66
9	385	511	428	439	514	–	573	394	271	419	65
12	422	521	504	457	512	–	556	445	293	431	63
1960											
3	459	485	518	501	566	–	288	477	268	412	57
6	382	507	522	377	392	–	295	353	248	334	68
9	461	502	482	435	430	–	311	361	205	382	71
11	376	417	465	378	445	–	425	340	224	402	–
1961											
3	436	467	393	395	347	–	317	350	238	295	76
6	346	455	454	351	389	–	563	385	205	326	83
12	290	379	447	343	354	–	281	383	200	456	92
1962											
3	308	300	466	347	374	–	319	280	205	457	74
6	324	459	432	367	385	–	591	432	219	247	77
9	347	411	488	378	320	–	606	319	217	306	91
1963											
3	326	419	432	323	302	–	451	300	201	213	72
6	353	422	352	355	346	–	435	198	197	322	156
9	317	326	317	371	345	–	383	173	182	292	78
1964											
4	331	375	430	370	360	–	317	229	178	270	68
9	336	452	376	378	331	–	256	232	149	277	87

1965											
3	381	399	490	465	–	365	401	224	191	327	89
9	297	287	302	307	–	278	732	327	226	350	99.6
1966											
4	237	247	265	267	–	254	633	277	129	215	101
10	236	267	344	300		255	472	187	135	316	101.6
1967											
3	301	271	358	330	–	264	383	304	159	355	96.5
9	286	405	400	353	–	290	715	79	151	415	92
1968											
3	361	465	410	343	–	316	533	132	128	568	101
9	365	369	370	379	–	321	660	304	187	546	112.9
1969											
4	289	312	409	302	.	380	486	353	249	480	101.1
9	333	327	344	294	.	304	697	103	219	261	296
1970											
4	341	401	420	301	–	340	645	380	238	308	137.4
9	249	309	285	235	–	271	614	250	185	203	159
1971											
3	321	274	272	279	–	271	513	211	157	259	133
10	288	291	356	284	–	289	437	195	158	319	137
1972											
3	216	193	270	251	.	232	327	256	140	300	136
9	267	206	291	284	–	230	544	229	118	368	123.4
1973											
3	255	261	293	289	–	280	394	183	196	225	115.5
9	230	256	230	258	–	267	480	189	149	247	123.7
1974											
3	256	326	288	293	–	309	547	234	144	508	120.8
9	230	247	259	240	.	287	352	255	137	538	164.9
1975											
3	193	286	239	259	–	255	258	252	129	329	159.5

NOTE: Levels in particles per cubic centimetre as measured by a konimeter

a Primary crushing and screening until March 1965. From September 1965 only primary crushing and not secondary crushing and screening

b Total mine ventilation

SOURCE: See Table D.1.

TABLE D.3

Average dust levels for selected underground locations and operations within gold mines 1960–75

Year/ Month	Headings drilling	Headings loading	Raises drilling	Stopes drilling	Stopes scraping	Dumping	Under-ground crusher	Main drives and cross cuts	Primary crushing	Cubic feet[a] per minute per ton hoisted per day (thousands)
1960										
6	456	467	586	406	369	–	342	198	476	59.2
11	425	476	591	388	373	522	458	276	397	62.7
1961										
6	447	491	680	402	191	455	489	211	523	63.7
12	421	453	627	437	401	461	513	185	441	73.8
1962										
3	439	486	628	383	338	430	440	194	433	78.0
9	388	401	628	370	460	412	475	160	360	68.4
1963										
3	342	363	646	330	351	347	338	154	341	75.1
9	362	370	339	305	316	340	280	153	312	74.9
1964										
4	349	378	578	299	252	400	226	148	348	72.0
9	360	341	548	297	261	346	420	128	354	73.8
1965										
3	270	282	888	254	293	400	238	138	290	70.0
9	285	336	405	301	275	312	234	151	116	70.6
1966										
4	300	298	363	261	271	–	294	116	208	63.2
9	328	319	356	272	248	–	162	164	152	69.6
1967										
3	268	320	356	262	251	–	147	124	194	77.3
9	248	255	377	233	220	–	144	136	176	88.0

1968										
3	278	270	396	228	233	227	130	107	322	80.7
9	279	258	337	281	238	309	164	134	202	73.3
1969										
4	302	296	297	144	279	294	128	99	286	77.4
9	311	311	309	175	259	427	108	113	181	80.5
1970										
4	295	295	351	244	282	352	234	117	334	77.7
9	237	274	378	286	223	249	137	173	258	76.4
1971										
3	260	340	480	288	323	433	236	171	305	76.0
10	257	312	339	292	282	338	151	186	450	79.9
1972										
3	210	250	264	235	247	263	146	133	185	79.0
9	271	284	250	227	233	287	148	147	455	74.8
1973										
3	253	308	220	253	224	–	142	129	720	63.2
9	206	325	382	204	223	–	110	126	308	60.9
1974										
3	238	277	343	267	353	–	214	174	476	80.1
9	313	309	289	275	271	–	367	95	304	80.3
1975										
3	283	338	335	294	212	–	377	193	474	91.9

NOTE: Levels in particles per cubic centimetre as measured by a konimeter

a Total mine ventilation

SOURCE: See Table D.1

TABLE D.4

Average dust levels for selected underground locations and operations within nickel mines 1964–75

Year/ Month	Headings drillings	Headings loading	Raises drilling	Stopes drilling	Stopes scraping	Dumping	Under-ground crusher	Main drives and cross cuts	Primary crushing	Cubic feet[a] per minute per ton hoisted per day (thousands)
1964										
4	526	471	643	391	381	519	359	201	372	60.2
9	480	597	682	422	478	580	387	240	388	57.2
1965										
3	584	546	743	441	409	562	489	249	353	52.2
9	527	576	846	412	565	553	497	195	535	50.0
1966										
4	587	563	727	415	453	–	454	227	483	52.6
9	554	522	592	214	428	–	385	235	435	53.3
1967										
3	509	552	566	388	426	–	452	220	567	66.8
9	497	487	561	354	427	–	433	216	457	52.4
1968										
3	457	570	574	376	379	496	376	287	511	48.1
9	406	446	472	286	369	459	337	321	419	49.2
1969										
4	446	397	311	318	338	418	373	179	494	51.1
9	446	420	258	310	375	520	398	194	460	51.4
1970										
4	328	478	454	371	396	500	502	233	525	52.2
9	384	471	406	359	354	394	384	227	645	57.3
1971										
3	383	485	399	333	378	399	437	235	740	61.9
10	365	418	331	305	379	407	500	207	593	65.9

1972										
3	435	482	524	325	353	484	455	276	554	71.0
9	396	405	524	311	303	376	396	158	460	84.6
1973										
3	341	374	376	350	377	–	375	214	432	79.5
9	296	326	284	275	359	–	410	114	434	87.8
1974										
3	331	437	451	325	412	–	450	166	445	80.5
9	351	416	244	295	378	–	332	71	362	96.8
1975										
3	375	428	450	311	374	–	495	208	224	86.5

NOTE: Levels in particles per cubic centimetre as measured by a konimeter

a Total mine ventilation

SOURCE: See Table D.1.

TABLE D.5

Fatal injury experience by metal group, company, and location of work for all companies operating in 1974

NOTE: Column A is number of employees in 1974; B is frequency of fatal injuries per million man-hours in 1974; C is average frequency per million man-hours 1970–4.

Metal group and company	Total			Underground			Open pit			Reduction, concentrator and metallurgical plants			Shops and surface		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Gold															
Bulora Mining Company Ltd	138	0	0.584	49	0	1.222				23	0	0	66	0	0
Campbell Red Lake Gold Mines	313	0	0.350	165	0	0.702				48	0	0	100	0	0
Dickenson Mines Ltd	226	0	0.866	120	0	1.527				40	0	0	66	0	0
Dome Mines Ltd	713	0	0.141	402	0	0.229				69	0	0	242	0	0
Kerr Addison	490	0	0.601	304	0	0.912				47	0	0	140	0	0
Willroy Mines Ltd–Macassa Div.	284	1.983	0.873	182	3.422	1.483				18	0	0	84	0	0
Pamour Porcupine Mines Ltd–Schumacher Div.	401	0	0.249	235	0	0.418				40	0	0	126	0	0
Pamour Porcupine Mines Ltd	717	0.756	0.418	458	1.226	0.689				66	0	0	193	0	0
Ross Mine	114	0	0	45	0	0				27	0	0	42	0	0
Total gold	3,396	0.317	0.419	1,960	0.562	0.711				377	0	0	1,059	0	0
Iron															
The Adams Mine	397	0	0				86	0	0	104	0	0	207	0	0
Algoma Ore	763	0	0	309	0	0				157	0	0	297	0	0
Caland Ore Company Ltd	442	0	0				94	0	0	102	0	0	246	0	0
The Griffith Mine	515	0	0				173	0	0	84	0	0	258	0	0
Marmoraton Mining Company	310	0	0				93	0	0	62	0	0	155	0	0
National Steel (Moose Mountain)	240	0	0				64	0	0	136	0	0	40	0	0
Sherman Mine	447	0	0				136	0	0	104	0	0	207	0	0
Steep Rock Iron Mines Ltd	601	0	0.392	0	0	4.598	165	0	0	153	0	0	283	0	0.344
Total iron	3,715	0	0.057	309	0	0.408	811	0	0	902	0	0	1,693	0	0.061
Miscellaneous industrials															
Canada Talc	42	0	0	22	0	0	1	0	0	8	0	0	11	0	0
Canadian Johns-Manville	144	0	0				36	0	0	42	0	0	66	0	0
Canadian Rock Salt Co. Ltd	243	2.026	0.868	123	4.102	0.876				70	0	0	50	0	2.426

Domtar-Sifto Salt	214	0	0	143	0	0				9	0	0	62	0	0
Hedman Mines Limited	19	0	0				2	0	0	12	0	0	5	0	0
Indusmin Ltd–Nepheline Syenite Div.	108	0	0				12	0	0	47	0	0	49	0	0
Indusmin Ltd–Silica Div.	77	0	0				12	0	0	39	0	0	26	0	0
Sobin Chemicals	83	0	0				9	0	0	38	0	0	36	0	0
Total Misc. industrials	930	0.554	0.230	288	1.856	0.389	72	0	0	265	0	0	305	0	0.363
Copper															
Falconbridge Copper–Sturgeon Lake	58	0	0		0	0	13	0	0	15	0	0	30	0	0
Mattabi Mines Ltd	295	0	0.587				78	0	2.346	63	0	0	154	0	0
Noranda Mines Ltd–Geco Div.	599	1.687	0.336	227	4.445	0.874				129	0	0	243	0	0
Pamour-Schumacher-Copper	235	0	0	128	0	0				38	0	0	69	0	0
Selco Mining–South Bay	63	0	0	9	0	0				22	0	0	32	0	0
Texasgulf Canada Ltd	1,687	0.268	0.140	276	0	0	85	5.878	0.861	190	0	0	1,136	0	0.102
Willroy Mines Ltd–Manitouwadge	208	0	0.459	92	0	0.998				26	0	0	90	0	0
Total copper	3,145	0.449	0.233	732	1.353	0.478	176	2.731	1.239	483	0	0	1,754	0	0.069
Silver															
Agnico–Eagle Mines Ltd	71	7.003	1.363	37	14.843	2.957				6	0	0	28	0	0
Teck Corp. Ltd–Silverfields Div.	76	0	1.430	41	0	2.768				15	0	0	20	0	0
Total silver	147	3.565	1.395	78	7.365	2.859				21	0	0	48	0	0
Nickel-Falconbridge															
Falconbridge East Mine	174	3.181	0.719	174	3.181	0.719									
Falconbridge Mine	757	0.770	0.316	757	0.770	0.156									
Fecunis North Mine	183	0	0.802	183	0	0.802									
HBO Mine	171	0	0	171	0	0									
Strathcona Mine	558	0	0.413	558	0	0.413									
Falconbridge Electrical	92	0	0										92	0	0
Falconbridge Mechanical	309	0	0.355										309	0	0.355
Falconbridge Sundry	487	0	0										487	0	0
Onaping Electrical	119	0	0										119	0	0
Onaping Mechanical	396	0	0										396	0	0
Onaping Sundry	217	0	0										217	0	0
Falconbridge Mill	129	0	0							129	0	0			
Fecunis Mill	93	0	0							93	0	0			
Hardy Mill	15	0	0							15	0	0			
Strathcona Mill	130	0	0							130	0	0			
Falconbridge Smelter	630	0	0.351							630	0	0.351			
Geology and DD	124	4.522	0.833	124	4.522	0.833									
Total Falconbridge	4,584	0.360	0.230	1,967	0.880	0.350				997	0	0.215	1,620	0	0.066

TABLE D.5 (concluded)

NOTE: Column A is number of employees in 1974; B is frequency of fatal injuries per million man-hours in 1974; C is average frequency per million man-hours 1970–4.

Metal group and company	Total			Underground			Open pit			Reduction, concentrator and metallurgical plants			Shops and surface		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Nickel-INCO *Ltd*															
Clarabelle Open Pit	136	0	0				136	0	0						
Coleman Mine	331	0	0	331	0	0									
Copper Cliff North Mine	675	0.842	0.161	675	0.842	0.161									
Copper Cliff South Mine	571	0	0	571	0	0									
Crean Hill Mine	437	0	0.416	437	0	0.416									
Creighton Mine	1,635	0.678	0.368	1,635	0.678	0.368									
Frood-Stobie Complex	2,635	0.248	0.339	2,635	0.248	0.339									
Garson Mine	900	0	0.210	900	0	0.210									
Kirkwood Mine	136	0	1.161	136	0	1.161									
Levack Mine and Levack West Mine	1,568	0.387	0.268	1,568	0.387	0.268									
Shebandowan Mine and Mill	254	0	0	254	0	0									
Victoria Mine															
Clarabelle Mill	243									243	0	0			
Copper Cliff Mill	370									370	0	0			
Creighton Mill	32									32	0	0			
Frood-Stobie Mill	195									195	0	0			
Levack Mill	158									158	0	0			
Copper Cliff Smelter Complex	4,225									2,516	0	0.029	1,664	0	0.183
Copper Cliff Copper Refinery	1,130									1,130	0	0			
Copper Cliff Nickel Refinery	346									346	0	0			
Port Colborne	1,658									1,658	0	0			
Iron Ore Recovery Plant	591									591	0	0			
Total INCO	18,181	0.161	0.152	9,142	0.327	0.301	136	0	0	7,239	0	0.013	1,664	0	0.183
Nickel – Other															
Noranda-INCO-Langmuir	129	0	0	69	0	0				27	0	0	33	0	0
Consolidated Canadian Faraday–Werner Lake	52	0	0							34	0	0	18	0	0
Total nickel	22,946	0.194	0.162	11,178	0.425	0.308	136	0	0	8,297	0	0.035	3,335	0	0.094

Uranium															
Denison Mines Ltd	795	0	0.271	386	0	0.271				94	0	0	315	0	0
Rio Algom Mines Ltd	837	0	0.498	468	0	0.967				104	0	0.968	265	0	0
Total uranium	1,632	0	0.389	854	0	0.638				198	0	0.495	580	0	0
Miscellaneous metals															
Chromasco Corp	282	0	0.399				5	0	0	187	0	0.528	90	0	0
Diamond drillers															
Bradley Bros Ltd	84	0	0										84	0	0
Canadian Longyear Ltd	28	0	0										28	0	0
Continental Diamond Drilling Co. Ltd	12	0	0										12	0	0
Heath and Sherwood	142	0	0	27	0	0							115	0	0
Midwest Drilling–Division of Germac Enterprises Ltd	38	0	0										38	0	0
N. Morissette Diamond Drilling Ltd	125	0	0	49	0	0							76	0	0
Total diamond drillers	429	0	0	76	0	0							353	0	0
Shaft sinking															
Boart Blasthole Canada Ltd	16	0	0	7	0	0							9	0	0
Cementation	26	0	0										26	0	0
Dravo Corp	41	0	0.978	28	0	1.153							13	0	0
Patrick Harrison	97	0	0.399	75	0	0.699							22	0	0
MacIsaac Mining and Tunnelling Co Ltd	540	0	0.761	370	0	1.023				2	0	0	168	0	0
J.S. Redpath Ltd	96	4.605	1.219	76	5.771	1.719							20	0	0
Ross, Findlay Ltd	9	0	0	9	0	0									
Total shaft sinking	825	0.580	0.731	565	0.849	1.005				2	0	0	258	0	0
Total	37,447	0.226	0.217	16,040	0.539	0.446	1,200	0.405	0.160	10,732	0	0.045	9,475	0	0.066

TABLE D.6

Estimated distribution of the workforce in the mining industry 1971

	Proportion of employees
Age (years)[a]	
< 20	0.039
20–24	0.179
25–29	0.132
30–34	0.117
35–39	0.111
40–44	0.108
45–49	0.098
50–54	0.088
55–59	0.073
> 60	0.055
Work experience with company (years)[b]	
< 1	0.119
1–5	0.141
> 5	0.740
Shift[c]	
7–3	0.589
3–11	0.284
11–7	0.127
Category of personnel[d]	
Unskilled and semi-skilled	0.35–0.65
Skilled trades	0.45–0.15
Engineering/Technical	0.05
Management/Supervision	0.10
Clerical	0.05

a From Statistics Canada, *Census of Canada, 1971*, Ottawa, 1975

b Based on data supplied by INCO Ltd

c See note *b*

d Data provided to the Commission by companies. The higher percentage of unskilled and semi-skilled personnel applies in operations that are primarily underground and do not have complete processing plants

TABLE D.7

Non-fatal injury experience by metal group, company, and location of work for all companies operating in 1974

NOTE: Column A is number of employees in 1974; B is frequency of non-fatal injuries per million man-hours in 1974; C is average frequency per million man-hours 1970–4.

	Total			Underground			Open pit			Reduction, concentrator, and metallurgical plants			Shops and surface		
Metal group and company	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Gold															
Bulora Mining Company Ltd	138	51.90	25.14	49	57.60	34.20				23	95.10	31.37	66	32.40	10.99
Campbell Red Lake Gold Mines	313	13.60	11.56	165	19.90	19.68				48	11.00	6.84	100	5.10	2.02
Dickenson Mines Ltd	226	4.50	13.85	120	8.40	19.85				40	0	2.79	66	0	7.80
Dome Mines Ltd	713	29.10	39.32	402	38.40	54.07				69	38.90	23.09	242	11.00	13.89
Kerr Addison	490	14.00	17.03	304	18.50	21.58				46	0	8.04	140	7.90	8.32
Willroy Mines Ltd–Macassa Div.	284	49.60	58.51	182	75.30	86.02				18	26.00	40.25	84	11.50	14.39
Pamour Porcupine Mines Ltd–Schumacher Div.	401	15.90	31.62	235	15.80	46.03				40	55.70	15.94	126	4.20	9.61
Pamour Porcupine Mines Ltd	717	2.30	18.09	458	3.70	25.72				66	0	7.66	193	0	5.85
Ross Mine	114	100.80	64.19	45	197.60	138.40				27	74.90	43.21	42	23.80	22.68
Total gold	3,396	21.72	28.24	1,960	28.36	39.15				377	26.79	15.58	1,059	8.36	9.69
Iron															
The Adams Mine	397	16.80	26.53				86	17.90	54.27	104	39.50	32.47	207	4.90	12.26
Algoma Ore	763	18.40	20.83	309	10.10	23.34				157	26.80	22.21	297	21.30	17.57
Caland Ore Company Ltd	442	24.70	32.73				94	42.40	61.30	102	24.20	43.30	246	18.20	17.50
The Griffith Mine	515	7.20	14.52				173	8.10	9.62	84	5.50	24.21	258	7.20	10.80
Marmoraton Mining Co.	310	22.80	10.20				93	11.70	7.93	62	61.30	18.70	155	14.00	8.16
National Steel (Moose Mountain)	240	44.70	36.65				64	39.70	25.30	136	26.40	31.50	40	114.70	75.40
Sherman Mine	447	39.10	31.08				136	35.80	37.90	104	79.20	55.10	207	21.10	15.13
Steep Rock Iron Mines Ltd	601	10.70	17.58			72.76	165	15.00	20.32	153	9.70	19.18	283	8.70	11.01
Total iron	3,715	20.69	22.74	309	10.1	27.78	811	22.01	27.94	902	31.30	30.26	1,693	15.98	15.00
Miscellaneous Industrials															
Canada Talc	42	34.90	39.39	22	42.30	58.44	1	0	0	8	60.40	67.77	11	0	0
Canadian Johns-Manville	144	35.50	26.94				36	42.90	21.53	42	24.30	9.33	66	38.60	26.42
Canadian Rock Salt Co. Ltd	243	60.80	58.19	123	77.90	70.11				70	34.20	25.34	50	57.80	84.90
Domtar-Sifto Salt	214	38.60	24.03	143	55.40	28.98				9	0	29.80	62	8.20	10.52

TABLE D.7 (continued)

NOTE: Column A is number of employees in 1974; B is frequency of non-fatal injuries per million man-hours in 1974; C is average frequency per million man-hours 1970–4.

	Total			Underground			Open pit			Reduction, concentrator, and metallurgical plants			Shops and surface		
Metal group and company	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Hedman Mines Ltd	19	53.60	48.22				2	0	0	12	44.70	60.90	5	100.20	46.48
Indusmin Ltd–Nepheline Syenite Div.	108	4.70	10.47				12	0	9.56	47	10.80	8.76	49	0	12.97
Indusmin Ltd–Silica Div.	77	26.60	45.91				12	0	42.33	39	25.70	45.25	26	40.40	50.62
Sobin Chemicals	83	38.90	35.76				9	0	0	38	56.80	52.88	36	29.50	28.29
Total Misc. industrials	930	39.34	33.24	288	65.08	48.99	72	21.71	24.78	265	30.52	29.89	305	28.11	31.60
Copper															
Falconbridge Copper–Sturgeon Lake	58	41.10	41.10				13	180.05	180.50	15	0	0	30	0	0
Mattabi Mines Ltd	295	12.60	24.77				78	5.90	28.16	63	22.40	15.23	154	12.10	25.27
Noranda Mines Ltd–Geco Division	599	35.40	19.97	227	51.10	31.01				129	26.70	15.66	243	25.40	11.81
Pamour-Schumacher-Copper	235	25.80	27.34	128	26.40	31.83				38	0	12.16	69	38.80	25.45
Selco Mining–South Bay	63	31.60	26.65	9	54.90	17.60				22	46.20	46.83	32	15.30	17.31
Texasgulf Canada Ltd	1,687	4.60	5.34	276	9.30	12.96	85	17.60	11.20	190	18.50	21.54	1,136	0.75	1.22
Willroy Mines Ltd–Manitouwadge	208	36.00	32.60	92	53.90	52.89				26	63.00	19.66	90	11.50	8.67
Total copper	3,145	15.40	14.36	732	31.13	30.92	176	24.58	18.58	483	22.70	17.27	1,754	6.71	6.08
Silver															
Agnico–Eagle Mines Ltd	71	63.00	55.88	37	118.70	79.83				6	0	23.86	28	16.20	34.59
Teck Corp. Ltd–Silverfields Div.	76	58.10	54.32	41	117.00	91.33				15	0	20.81	20	0	10.46
Total silver	147	60.61	55.12	78	117.85	85.77				21	0	22.00	48	9.89	25.53
Nickel-Falconbridge															
Falconbridge East Mine	174	31.80	23.74	174	31.80	23.74									
Falconbridge Mine	757	27.70	26.20	757	27.70	26.20									
Fecunis North Mine	183	34.30	33.67	183	34.30	33.67									
HBO Mine	171	30.00	30.18	171	30.00	30.18									
Strathcona Mine	558	35.60	35.07	558	35.60	35.07									
Falconbridge Electrical	92	17.00	5.66										92	17.00	5.66

Falconbridge Mechanical	309	25.70	19.18										309	25.70	19.18
Falconbridge Sundry	487	1.30	3.08										487	1.30	3.08
Onaping Electrical	119	13.70	12.97										119	13.70	12.97
Onaping Mechanical	396	34.90	29.25										396	34.90	29.25
Onaping Sundry	217	1.70	3.95										217	1.70	3.95
Falconbridge Mill	129	7.20	5.47							129	7.20	5.47			
Fecunis Mill	93	64.70	25.82							93	64.70	25.82			
Hardy Mill	15	0	24.31							15	0	24.31			
Strathcona Mill	130	8.20	12.87							130	8.20	12.87			
Falconbridge Smelter	630	36.90	26.17							630	36.90	26.17			
Geology and DD	124	40.70	14.16	124	40.70	14.16									
Total Falconbridge	4,584	25.60	21.53	1,967	31.97	28.68				997	30.71	21.37	1,620	16.36	13.09
Nickel-INCO Ltd															
Clarabelle Open Pit	136	75.50	36.11				136	75.50	36.11						
Coleman Mine	331	182.10	176.31	331	182.10	176.31									
Copper Cliff North Mine	675	96.90	71.80	675	96.90	71.80									
Copper Cliff South Mine	571	126.40	107.01	571	126.40	107.01									
Crean Hill Mine	437	129.80	85.79	437	129.80	85.79									
Creighton Mine	1,635	122.50	78.83	1,635	122.50	78.83									
Frood-Stobie Complex	2,635	109.00	76.80	2,635	109.00	76.80									
Garson Mine	900	103.10	82.82	900	103.10	82.82									
Kirkwood Mine	136	137.10	78.40	136	137.10	78.40									
Levack Mine and Levack West Mine	1,568	143.00	130.40	1,568	143.00	130.40									
Shebandowan Mine and Mill	254	119.00	95.43	254	119.00	95.43									
Victoria Mine															
Clarabelle Mill	243	72.60	59.03							243	72.60	59.03			
Copper Cliff Mill	370	48.20	74.76							370	48.20	74.76			
Creighton Mill	32	0	21.17							32	0	21.17			
Frood-Stobie Mill	195	27.90	47.67							195	27.90	47.67			
Levack Mill	158	163.50	135.67							158	163.50	135.67			
Copper Cliff Smelter Complex	4,180	39.00	54.93							2,516	50.50	37.39	1,664[a]	20.10	17.08
Copper Cliff Copper Refinery	1,130	129.10	93.20							1,130	129.10	93.20			
Copper Cliff Nickel Refinery	346	25.70	26.50							346	25.70	26.50			
Port Colborne	1,658	45.10	34.76							1,658	45.10	34.76			
Iron Ore Recovery Plant	591	42.60	35.00							591	42.60	35.00			
Total INCO	18,181	85.29	62.88	9,142	121.53	90.87	136	75.55	36.11	7,239	60.77	46.97	1,664	20.10	17.08
Nickel – Other															
Noranda-INCO-Langmuir	129	8.40	9.04	69	7.40	7.72				27	0	13.95	33	18.1	8.93
Consolidated Canadian Faraday–Werner Lake	52	9.70	17.88							34	0	7.76	18	0	6 49
Total nickel	22,946	72.56	54.76	11,178	104.48	79.97	136	75.55	36.11	8,297	56.67	44.01	3,335	17.92	15 06

TABLE D.7 (concluded)

NOTE: Column A is number of employees in 1974; B is frequency of non-fatal injuries per million man-hours in 1974; C is average frequency per million man-hours 1970–4.

Metal group and company	Total			Underground			Open pit			Reduction, concentrator, and metallurgical plants			Shops and surface		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Uranium															
Denison Mines Ltd	795	31.80	19.75	386	53.60	30.31				94	30.50	13.56	315	5.50	7.52
Rio Algom Mines Ltd	837	22.20	21.53	468	38.50	36.25				104	4.90	9.10	265	3.80	4.81
Total uranium	1,632	26.77	20.68	854	45.38	33.45				198	16.40	11.38	580	4.66	6.11
Miscellaneous Metals															
Chromasco Corp	282	105.20	109.18				5	195.30	98.46	187	127.00	122.04	90	54.40	65.87
Diamond drillers															
Bradley Bros Ltd	84	108.20	102.33			215.57							84	108.20	109.18
Canadian Longyear Ltd	28	80.30	51.75										28	79.80	51.75
Continental Diamond Drilling Co. Ltd	12	385.10	119.65			120.00							12	385.10	119.65
Heath and Sherwood	142	105.80	100.17	27	321.30	167.65							115	64.70	70.84
Midwest Drilling–Division of Germac Enterprises Ltd	38	50.40	76.33										38	50.40	76.33
N. Morissette Diamond Drilling Ltd	125	57.80	61.90	49	97.10	64.02							76	36.60	59.96
Total diamond drillers	429	91.77	82.69	76	188.62	108.63							353	76.08	73.62
Shaft Sinking															
Boart Blasthole Canada Ltd	16	38.40	85.79	7	94.90	101.60							9	0	72.00
Cementation	26	0	114.62			250.86							26	0	48.00
Dravo Corp.	41	25.10	41.80	28	37.50	43.74							13	0	29.64
Patrick Harrison	97	41.90	35.52	75	55.00	48.92						0	22	0	20.19
MacIsaac Mining and Tunnelling Co. Ltd	540	26.50	23.44	370	34.70	25.17				2	0	12.73	168	8.60	18.68
J.S. Redpath Ltd	96	32.20	58.52	76	34.60	61.88							20	22.80	50.31
Ross, Findlay Ltd	9	123.50	227.76	9	123.50	226.78									
Total shaft sinking	825	29.15	39.73	565	39.08	44.68				2	0	8.96	258	7.50	27.43
Total	37,447	53.71	44.88	16,040	83.05	66.88	1,200	29.98	28.38	10,732	51.57	41.24	9,475	16.16	16.51

a Approximate figure based on an average of 2,000 hours of work per man per year.

TABLE D.8

Non-fatal injuries 1970–4 by type of accident and bodily region of injury

	Proportion of injuries 1974	Proportion of injuries 1970–4
Type of accident		
Slips and falls	0.246	0.272
Collisions	0.170	0.180
Over-exertion	0.178	0.182
Caught between	0.109	0.115
Free-falling objects	0.058	0.051
Rock falls	0.076	0.065
Propelled flying objects	0.024	0.037
Extreme temperature	0.030	0.025
Inhalation	0.043	0.019
Nails, splinters	0.020	0.016
Run of muck	0.009	0.011
Explosives	0.004	0.005
Other	0.033	0.021
Region of injury		
Head and neck	0.126	0.119
Torso	0.296	0.308
Hands, arms, legs, and feet	0.569	0.561
Other	0.009	0.012

SOURCE: Mines Accident Prevention Association of Ontario, *Annual Reports 1974–1975*

TABLE D.9

Comparison of actual deaths of Northern Ontario males with expected deaths for all Ontario males

All causes 9554 : 8410.26	Violent causes 1374 : 934.91	Motor vehicle accidents 468 : 368.34
		Suicide 192 : 147.12
		Other 714 : 419.45
	'Natural' Causes 8180 : 7475.35	Respiratory tuberculosis 39 : 25.62
		Cancer of lung 370 : 345
		Cancer of stomach 182 : 128.75
		Arteriosclerotic heart disease 3514 : 3060.78
		Hypertension 115 : 103.67
		Respiratory disease 578 : 542.86
		Balance 3382 : 3268.64

APPENDIX E: STUDIES CONDUCTED FOR THE COMMISSION

The mortality experience of persons on the Uranium Nominal Roll 1955–74 D. Hewitt, Associate Professor, Department of Preventive Medicine and Biostatistics, University of Toronto	With the Assistance of Statistics Canada, the Registrars General, the Workmen's Compensation Board, the Ministry of Health, and the Ministry of Natural Resources. Major results are included in chapter 3.
Radiogenic lung cancer in Ontario uranium miners 1955–74 D. Hewitt, Associate Professor, Department of Preventive Medicine and Biostatistics, University of Toronto	As above, except that the major results are included as appendix C.
Health and safety in mines F.D.K. Liddell, Professor of Medical Statistics, McGill University	An annotated bibliography on the pneumoconioses, asbestosis and silicosis, on lung cancer, and on chronic obstructive pulmonary disease.
Study of health and safety in metallurgical plants Jan H. Reimers and Associates Ltd	A study of health and safety aspects of the design and operation of metallurgical plants. Representative process flow sheets are included in chapter 5.